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Nutrient Requirements and Diet - A Review

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NUTRIENT REQUIREMENTS AND DIET--A REVIEW

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FOREWORD

Understanding the nature and dimensions of the world food problem and the policies available to alleviate it has been the focal point of the IIASA Food and Agriculture Program since it began in 1977.

Inadequate food consumption by a large number of people is the major food problem of the world. Though there is agreement among scholars that the problem is widespread, estimates of the number of hungry people vary considerably. Controversy also surrounds methods of estimating nutritional norms from data on household consumption surveys. Thus it is important to look at nutrient requirements from a physiological point of view.

Michiel Loewik in this paper provides such a review of nutritional requirements and diet.

Kirit S. Parikh
Program Leader
Food and Agriculture Program

PREFACE

This working paper was written in 1981 while I was a participant in the Young Scientists' Summer Program at IIASA

This paper is a state-of-the-art of the major nutritional problems in developing countries. It shows that not only hunger (protein-energy malnutrition), but also iron deficiency and vitamin A deficiency are serious problems in the developing countries.

The present knowledge on nutrition is much more detailed and sophisticated than is described in this working paper. In writing this paper I did not go into all the details because the Food and Agriculture Program at IIASA is working at a level of aggregation where these details have no significant impact on the ultimate results.

ACKNOWLEDGEMENTS

I would like to express my appreciation to Kirit Parikh and Mahendra Shah for their help and guidance during my three month stay at IIASA and in particular for their assistance and suggestions in preparing this paper. Special thanks also to Barbara Hauser and Cynthia Enzlberger for typing and editing this manuscript.

CONTENTS

1. INTRODUCTION

Food is required by the body for a variety of purposes. It must supply enough nutrients to maintain all body functions and movements and in addition it is needed for building up new tissues as is the case by pregnancy and growth in children. The extra requirements of lactating mothers have to be satisfied through the food they eat.

Food requirements can be estimated quantitatively in terms of nutrients that are known to be essential to human beings. When these requirements are not met by food intake, malnutrition and/or undernutrition will occur and the consequent possibility that nutritional diseases results. Malnutrition results from a deficiency in the diet of one or more nutrients (e.g. iron deficiency anemia) while undernutrition arises due to inadequate intakes of energy and protein. Nutritional deficiency diseases are characteristically of a chronic clinical nature.

Although all essential nutrients (fat, carbohydrate, protein, vitamins, minerals and trace elements) create deficiency syndromes when the intake is too low, most nutrients have not shown to be of major significance to public health. For instance, most of the trace elements are required by mankind but deficiencies have not been described under normal circumstances. Of course it is possible that in certain areas, under unusual circumstances, a certain deficiency disease occurs. For instance, rickets (vitamin D deficiency) is still found in crowded urban areas or by immigrants living in England where the practice of purdah still exists. Because the incidence of most of the "classical" deficiencies (for instance beri-beri and scurvy) is low and varies from country to country, this paper describes only the nutritional diseases that have a high prevalence and a high social impact.

The most severe and widespread nutritional deficiencies, especially among children are a consequence of protein and energy malnutrition (PEM). In addition to PEM, the most prevalent tropical malnutrition problems are vitamin A deficiency, iron and eventually folate deficiency anaemias, and endemic goiter (see Figure 1). Because endemic goiter is due to an iodine deficiency and the important sources of iodine are seafood and foods from iodine rich soils, there are a few preventive measures possible by changing the diet. For this reason this paper will not deal with this deficiency disease.

It is well known that diseases can influence nutritional status. Only the diseases that have a "major" impact on PEM, anaemia or xerophthalmia will be mentioned in this paper.

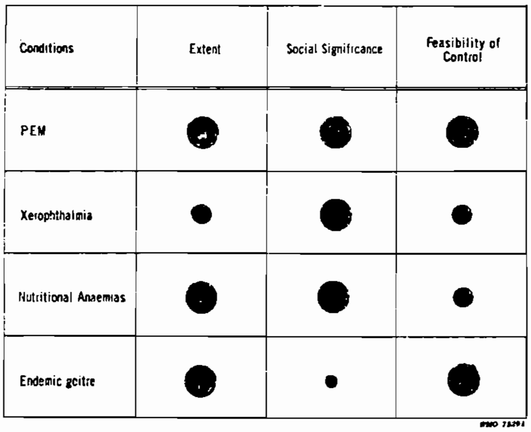
Food and nutrient intakes differ with income groups. Because income influences both the quantity and the quality of foods consumed, some attention will be paid to the general changes that occur in the consumption pattern with rising incomes.

Because nutrients are supplied by food, it is important to know which foods are rich in certain nutrients. The main food sources of energy, protein, iron and vitamin A are given in section 4.

2. NUTRITION PROBLEMS IN DEVELOPING COUNTRIES

2.1. Protein-energy malnutrition

No other nutritional disease compares in importance with protein-energy malnutrition (PEM). This form of malnutrition is highly prevalent in infants and young children in almost all developing countries. PEM can be defined as a range of pathological conditions arising from a deficiency of protein and energy,



[a] The size of the circle gives an indication of magnitude. PEM, protein–energy malnutrition.

Fig. 1. Priorities among nutritional deficiency conditions

Source: BEATON and BENGOA; 1976

which is commonly associated with infections. When the nutritional deficiencies are mild to moderate and prolonged the body of a growing child adapts by reducing its rate of growth. When the protein and energy restrictions are too great for the child's ability to reduce its growth rate, the body will "consume" its own tissues for metabolic purposes. This latter adaptation process also occurs in adults. The severe forms of PEM lead to death, while the less severe forms may have permanent effects on the growth and development of children. (Note: A human being can store energy in the form of fat, but the human body is not able to store protein and is completely dependent on the daily intake. In the case of inadequate protein intake, less important body protein will be used to supply the essential organs with enough protein). The occurrence of severe cases of PEM, even in small numbers, is an indicator of a much more extensive problem, i.e. the existence of a large number of mild and moderate but frequently unrecognized forms of PEM. (Davidson, et.al. 1975).

PEM covers a wide spectrum of pathological conditions, the extremes being nutritional marasmus and kwashiorkor and are as follows:

- Nutritional marasmus: a condition characterized by very low body weight for age, loss of subcutaneous fat, gross muscle wasting and absence of oedema. The children are irritable, fretful, or apathetic. Diarrhea is frequent. The muscles are weak and atrophic and this together with the lack of subcutaneous fat, gives the limbs the appearance of being just skin and bones. Nutritional marasmus is the childhood equivalent of starvation in adults. It is observed more frequently in infants and very young children.
- Kwashiorkor: a condition characterized by oedema and low body weight for age. Other symptoms are anorexia, depression or apathy. Some degree of anaemia is always present and may be severe, though this is unusual. The serum albumin level is low while there is fatty infiltration of the liver. The following signs may also be present but are by no means universal or very marked: muscle wasting, dermatosis, hepatomegaly, hair changes, diarrhoea and mental changes. The syndrome is most frequently observed in

children aged 1-3 years and is precipitated by an infection or more commonly by a series of infections occurring successively or concurrently (Demaeyer, 1976).

Because marasmus and kwashiorkor are the extremes of a wide spectrum it is more convenient, from the point of view of public health, not to emphasize the distinctions but to use the more general term "protein-energy malnutrition".

Protein-energy malnutrition results from the interaction of several factors among which two are more or less are directly responsible for the disease and act synergically. They are:

(a) A quantitatively insufficient and/or qualitatively inadequate dietary intake. Marasmus is due to both insufficient calorie and protein intake, while kwashiorkor is due to a protein deficiency.

(b) Infectious processes such affecting gastro-intestinal and respiratory tracts and infectious diseases of childhood (for instance measles, whooping cough, malaria, intestinal parasites and particular diarrhoeal diseases).

Although it is well known that infections adversely affect the nutritional status it is very difficult to quantify these effects.

The different types of malnutrition observed in different age groups is mainly due to breast feeding and weaning practices. (Note: weaning means the total cessation of breast feeding.) When weaning occurs early, i.e. before one year, and the infants are provided with artificial feeding (frequently overdiluted milk formulas) the marasmus type of PEM is mainly observed. Weaning is often associated with infectious diarrhoea and this disease will result in the nutritional status of the child deteriorating. Marasmus is practically the only form of PEM seen in infants below 6 months. It may arise when the child is weaned immediately after birth. When weaning occurs late, severe cases of malnutrition are more frequently observed during the second, third and fourth years of life, and the kwashiorkor type of PEM most commonly appears (see Figure 2).

2.2. Nutritional anaemias

There are three types of nutritional anaemia, namely:

(a) iron deficiency

(b) folate deficiency

(c) vitamin B12 deficiency

The most common type of anaemia is caused by iron deficiency. This anaemia is most prevalent among infants and women (menstruating or pregnant), while it is rare in men, without parasite infections. The most common cause of folate deficiency is pregnancy and lactation. The prevalence of vitamin B12 deficiency anaemia is very low and there is little evidence that this anaemia represents an important public health problem.

Nutritional anaemia may be defined as the condition that results from the inability of the erythropoietic tissue to maintain a normal haemoglobin concentration due to an inadequate supply of one or more essential nutrients (Layrisse, et al, 1976). The diagnosis of anaemia in an individual depends on measuring the haemoglobin concentration and demonstrating that it is below a certain level. Because there are variations in the "normal" haemoglobin concentration of individuals, the classification based on a certain level of hoemoglobin is of course arbitrary.

The basic etiology of iron deficiency is an imbalance between the amount of iron absorbed and the amount of iron lost. This imbalance can be produced by:

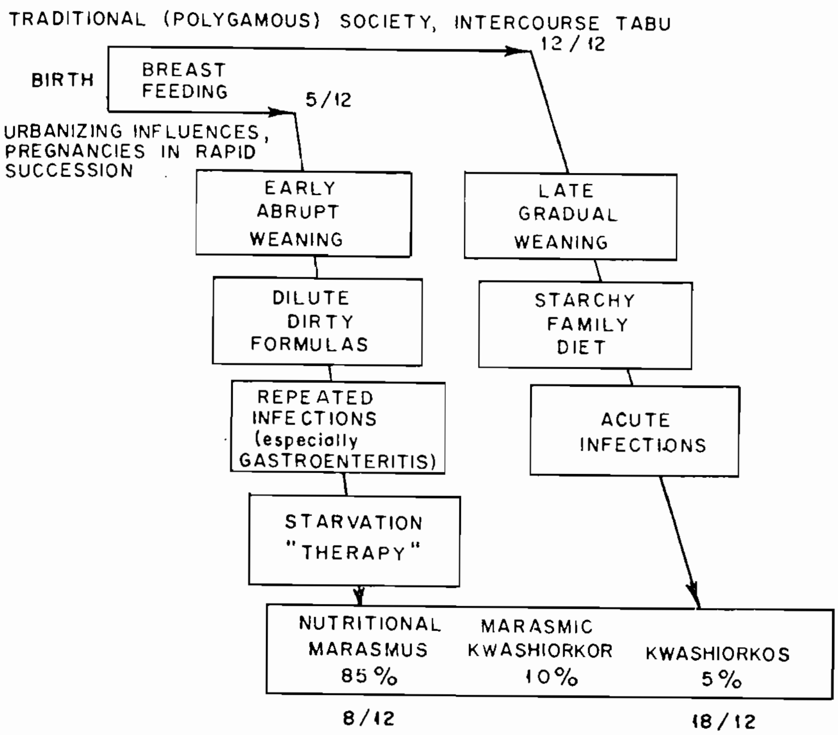


Fig. 2. Paths leading from early weaning to nutritional marasmus and from protracted breast feeding to kwashiorkor

Source: McLAREN; 1975

- too low intakes
- poor biological availability of dietary iron
- increased losses (for instance by parasite infestations and gastro intestinal diseases)
- increased requirement (pregnancy, menstruation or the the growth of the child)

- a combination of these factors.

In the physiological sense, therefore, three groups of people are particularly vulnerable to iron deficiency:

- young children, 6-18 months
- menstruating women
- pregnant women.

In the pathological sense all persons subject to chronic blood loss are also prone to develop iron deficiency. Because parasite infections are most prevalent among children, young children are vulnerable both from the physiological (growth) point of view and from the pathological sense.

The two major causes of iron deficiency are: blood loss and protein deficiency. It has been observed that there is a close correlation between decreased plasma protein and iron deficiency (Finch, 1975).

Haemosidirin and transferrin (both body proteins) store iron. These stores reach their lowest level between 12 and 20 months of age, during childhood and adolescence they increase slowly and reach adult levels in males around 20 years of age. Because of the additional iron requirements imposed by menstruation and pregnancy, most women have considerable lower iron stores than men living on a similar diet.

Deficient intake of folate is most often associated with artificial feeding of infants, low socio-economic class or excessive loss of folate due to prolonged cooking. The folates in food are namely heat labile. Folate deficiency causes the so called megaloblastic anaemia, because a deficiency produces a morphological change in the megaloblasts (developing red cells). Increased requirements for folate occur during periods of rapid growth, pregnancy and during lactation. Diseases, like diarrhoea, that affect the absorption of folate, decrease the resorption and thereby increase the "requirement". It is known that malaria increases the folate requirements. In subjects with normal nutrition, body stores of folate are sufficient to meet the usual requirements of the body for several months, even if no dietary folate is available. In the absence of severe iron deficiency anaemia, the significance of folate deficiency to the individual and the public health not clear.

Pernicious anaemia, or a vitamin B12 deficiency, is observed in strict vegetarians. The largely vegetarian diet consumed by people in many parts of India contains enough available vitamin to meet the body's requirements; presumably it comes from contamination of food and water supplies. People who habitually eat a diet rich in animal protein may consume up to 100 μg of vitamin B12 per day and have stores of the vitamin sufficient to meet the body's requirements for 3-5 years. Subjects who eat a vegetarian diet may consume less than 0.4 μg per day and have smaller stores. If the dietary supply of vitamin B12 is unavailable such subjects will develop overt deficiency within a few weeks or months. Increased demands for vitamin B12 occurs during pregnancy, but because of the body stores and the very low requirements for vitamin B12 this seldom causes pernicious anaemia. At present there is no evidence that vitamin B12 deficiency is an important public health problem.

Reduction of body stores of iron, folate and vitamin B12 may produce no symptoms or ill effects other than a reduced ability to respond to increased demands for these nutrients. Persons with mild anaemia frequently have no symptoms though others may notice pallor and various vague symptoms like fatigue, reduced powers of concentration, and sleeplessness. As the anaemia becomes more severe the patients may experience disturbances in respiratory, cardiovascular, renal, neuromuscular, and gastro-intestinal functions. Common systems are general fatigue and lassitude, breathlessness on exertion, giddiness, dimness of vision, headache, insomnia, pallor of skin, palpitation, anorexia and dyspepsia, tingling and "pins and needles" in the fingers and toes (Davidson et al., 1975). The severity of the clinical features are dependent not only on the degree of anaemia but also on the rapidity of its development.

Because vitamin B12 deficiency and to a lesser extent folate deficiency are, at the present time, no real public health problem this paper will concentrate only on the iron deficiency anaemia.

2.3. Xerophthalmia

Although xerophthalmia means "dryness of the eyes" it is now generally accepted to denote vitamin A deficiency of a severe degree threatening sight and life. Vitamin A is an essential component for general cellular metabolism and subcellular structures, while it specifically affects the eye. The clinical features of vitamin A deficiency start with night blindness and end up with blindness. The body is capable of storing considerable amounts of vitamin A in the liver. It may require two years of dietary depletion before a normal adult begins to show functional symptoms of tissue deficiency. In a child possessing meagre reserve catastrophic corneal destruction may appear within a few weeks or even days. Infants are born with relatively small liver vitamin A stores. Young infants depend on a rich source of vitamin A, such as breast milk from well nourished mothers, to build up body stores. So the breast feeding practice, especially how long, is an important factor in precipitating vitamin A deficiency. Because an infant has to build up a body store of vitamin A it is not surprising that it is noted that the younger the child, the more serious the manifestations are and the greater the mortality rate is. Males are apparently more vulnerable to vitamin A deficiency than females.

Clinical "pure" nutritional vitamin A deficiency is rare. The clinical signs of xerophthalmia are seldom present in a subject who has otherwise an acceptable nutritional status. The most common association is with protein energy malnutrition in the small child. (Oomen, 1976). When dietary protein intake is deficient, the proteins that play a role in the transport of vitamin A are not made in sufficient amounts. The result is that vitamin A is not adequately available to all kinds of body tissues. Signs of vitamin A deficiency may appear, although the vitamin A store in the liver could have prevented it.

The most serious public health aspect of vitamin A deficiency in societies is the sequela of blindness. Blindness at an early age leaves the child crippled physically and mentally. The earliest symptom, night blindness, and the earliest sign, dryness of the conjunctiva, cause little disability but are warning signals.

3. NUTRITIONAL REQUIREMENTS

3.1. General

An adequate supply of food is needed to maintain all body functions and daily activities at maximum efficiency, thus ensuring healthy life. The food needs can be estimated quantitatively in terms of energy and the major nutrients essential in human nutrition are known. Nutrient requirements differ for individuals according to their:

- age
- body size
- sex
- activity
- environmental conditions (for example temperature)
- physiological state (for instance pregnancy)

Daily allowances or nutritional standards, except those for energy, have been recommendations for nutrient intake levels which sufficiently exceed the average nutritional requirements to meet the physiological needs of nearly all of the population—a public health or statistical concept. It is important to make the distinction between requirement, i.e.the least amount needed, and recommended allowance, i.e.the amount which a group of experts have fixed upon as a desirable intake.

In attempting to give dietary allowances a "level of health" has to be sought and the degree of coverage for individuals that has to be achieved. Nearly all recommendations are based on prevention of depletion of body nutrients and not just on the prevention of clinical lesions. The resultant figures are thus higher than the level necessary to prevent clinical morbidity. Because criteria for optimal health are absent, it is possible that the proposed levels might not represent optimal health.

Besides all kinds of factors (for instance, age and activity) that influence nutrient requirement, there is an unpredictable variability among healthy individuals in their nutrient requirements. In existing practice there is an important difference between the expression of energy requirements and the expression of requirements for individual nutrients. In the case of energy, the requirement is the amount adequate to meet the needs of the average healthy person in a given age/sex/activity group and is obtained by measuring the intakes of healthy subjects. (Note: A consistent and cumulative excessive intake of energy usually leads to obesity.) For the other nutrients it is common to give an estimate of the upper range of individual requirements (see Figure 3).

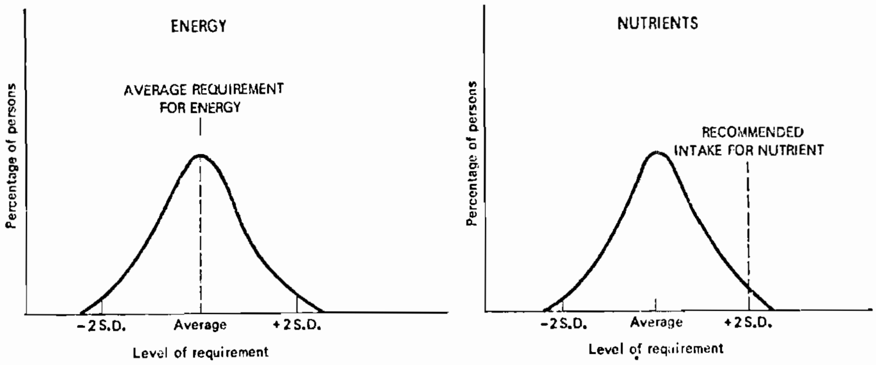


Fig. 3. Comparison of average requirement for energy and recommended intake for a nutrient
Note: It is assumed that in each case individual requirements are normally distributed about the mean

Source: BEATON and PATWARDHAN; 1976

Thus in the case of energy it is expected that the requirements of a group of individuals would be equally distributed above and below the average value. This is not the case for other nutrients and it is necessary to remember that most individuals have actual requirements below the recommended level. The energy requirements is an average value, and thus half of the individuals will need more and half less energy than is specified. In contrast, the recommended daily allowances are intended to cover the needs of 97.5% of the population.

Recommended allowances are intended to apply to healthy individuals and are largely based on studies with healthy individuals living in temperate climates. However most people, especially those who live in the developing countries, are living in an environment that can increase the nutrient needs. All kinds of diseases can deteriorate the absorption or can cause the loss of certain nutrients. Many infectious diseases increase the need for protein and other nutrients. Likewise, deficiencies of certain nutrients increase a persons susceptibility to infectious disease. Intestinal or urinary tract infections may cause substantial iron and protein loss. Intestinal tract infection and diarrhoea can dramatically lower the efficiency of digestion and nutrient absorption. Hookworm and roundworm infections can cause very high rates of iron and protein loss through bleeding. The nutrient requirements imposed by disease, malabsorption or those needed to provide rehabilitation of already malnourished people must be seen as additional requirements. The reason that these additional requirements are not included in the recommended allowances is that such a recommendation is very arbitrary and such a practice is costly (higher allowances), while the benefits are uncertain. The recommended allowances thus refer only to the amount of nutrients needed to maintain the health of the population.

3.2. Application of nutrient recommendations

Almost every publication of tables of nutrient requirements carries a statement similar to that of the Joint FAO/WHO Ad Hoc Expert Committee on Energy and Protein Requirements (1973), namely: nutrient recommendations should never be used as the sole basis for the evaluation of nutritional status. It is impossible to say whether or not an individual (or group) has had a sufficient intake of a certain nutrient to meet his or her (their) requirements. The only thing one can say is that the lower the intake (below the recommended level) the more likely it is that a person has a nutrient intake that is too low. The greater the proportion of individuals in a population who habitually have intakes of nutrients below the recommended daily allowance, the greater the risk that some of them will be consuming nutritionally inadequate diets. The more the habitual intake falls below the allowance and the longer the period of low intake is, the greater the risk of deficiency (Haverberg, 1977). Besides if the mean intake of a group (individual) is found to exceed the average requirement, it is still possible that some of the group may have deficient intakes.

Because of these possible errors, the individual variation, and the fact that individuals have true requirements below the recommended level, it is not possible to make a definite statement that an individual diet is adequate or inadequate, or that a certain percentage of a group is malnourished. Thus while requirements may be used to indicate the likelihood that a diet is satisfactory, they cannot provide complete and precise information. The big weakness of the "food balance sheet" approach for assessing national nutritional problems is that it is impossible to take these considerations into account. A survey of the intake and requirements of households in communities or of groups of individuals of a given age/sex category can indicate nutritional risk, i.e. the probability of deficiency in the populations studied, but deficient individuals or households cannot be identified from this information. In addition to dietary intake information, clinical biochemical and anthropometric measures are necessary to assess the nutritional status of individuals. Such an approach identifies who is deficient in what nutrients in relation to a set of standard measures.

Despite their limitations, nutritional standards can serve as useful guidelines or goals for population groups provided their limitations are recognized. The way the requirement standards are used should be determined by the end purpose, i.e., either as an assessment tool or as a target. At the population level, the standards can be used to compare intakes of different population groups or to evaluate the mean intake of the same population with time. The first is a crude indicator of the absolute magnitude of the problem at a given point in time, while the latter indicates an assessment of trends (improvements, stable or degeneration) on a relative basis.

The most often used indicator of the extent of nutritional inadequacies in large population groups is an energy deficit. This indicator is so often used because the allowances for energy are fairly rigid (no margin of safety) and because energy deficiency is also often associated with insufficient intake of specific nutrients, such as proteins and vitamins. Protein standards are not as meaningful indicators as calories, since protein requirements depend on many specific variables, such as protein quality, health conditions, and the calorie adequacy of the diet. Similarly, other nutrients are not suitable indicators, since deficiencies of specific nutrients are more often a serious local, regional or age-specific problem rather than a widespread phenomenon among population groups which consume diets adequate in energy.

If food availability, purchasing power, and other socio- economic factors permit, calorie intake will be proportional to needs, such that the average intake of a population can be compared directly with the average requirements predicted for the population. For almost all other nutrients, there is no reason to think that intake would be proportional to requirements (Haverberg, 1977). In most cases, deficiencies of protein as well as of vitamin and mineral deficiencies are the result of inadequate intake of food, being thus unavoidably associated with inadequate intakes of energy (FAO/WHO, 1976).

Although energy is the best indicator of nutritional adequacy it still has big shortcomings for use in large population groups, namely it does not account for inter - and intra household distribution.

It will be noted that the tables that are presented in the next paragraphs offer no information with reference to suitable nutrient intakes below the age of 6 months. Most of the expert committees considered that up to the age of at least 4 months all nutrient requirements are met by breast feeding, provided that the mother herself is adequately nourished. The weigths shown in tables are those of well nourished children in a North American population (Beaton and Patwardhan, 1976).

3.3. Energy

3.3.1. Energy requirements

Energy requirements are based on measurements of energy intake and expenditure in healthy subjects. The general method of approach on energy requirements is to set the requirements for a reference man or woman under well defined conditions and then to consider the variations by factors such as physical activity, body weight, age, climate, pregnancy and lactation. So the starting point is a reference man and reference woman (for a definition see Appendix 1) with a way of life corresponding to a selected energy level, while a factoral approach is used to adjust the allowances for various factors.

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

The energy requirements of individuals depend on 4 variables interrelated in a complex way, namely:

(a) physical activity

(b) age

(c) body size and composition

(d) climate and other ecological factors.

The factor that alters the daily energy expenditure most is physical activity. The Expert Committee of the FAO/WHO (1973) makes a rough classification in four categories namely: light activity, moderately active, very active and exceptionally active. For an illustration of how energy expenditure changes with these four groups see Appendix 2.

The energy expenditure of adults alters with age because of:

(a) changes in body weight or body composition (active cell mass decreases; body fat content increases; total body weight increases)

(b) a decrease in the basal metabolic rate (active cell mass decreases beyond middle age)

(c) a decline in physical activity (from the age of 40 onwards)

(d) an increased prevalence of diseases and disabilities (especially after the age of 70).

The Expert Committee of the FAO/WHO (1973) recommended that the average energy requirements of men and women be regarded as unchanged from 20 up to 39 years of age. Energy requirements thought to decrease by 5% for each decade between the age of 40 and 59 years, and by 10% from 60 to 69 years of age, for age 70 and above another reduction of 10% is suggested (see Table 1).

Table 1. 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

Source: WHO; 1973

Body size and composition affects energy expenditure by an effect on:

(a) resting metabolism (based on fat-free body mass)

(b) the physical work of moving the whole body, or large parts of the body

(c) the work of standing, maintaining posture and small movements of limbs.

Tables 2 and 3 give the average energy requirements of men and women in different occupational groups according to body weight (the requirements for the reference man and reference woman are shown in bold type). Note that as there are differences in both body size and composition between men and women there are also differences in energy requirements.

The Expert Committee of the FAO/WHO (1973) considered that there is no quantifiable basis for correcting the energy requirements according to climate

Table 2. The effects of body weight and occupation on energy requirements of men

Body weight (kg)	Light activity (kcal)	Light activity (MJ)	Moderately active (kcal)	Moderately active (MJ)	Very active (kcal)	Very active (MJ)	Exceptionally active (kcal	Exceptionally active (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

Source: WHO; 1973

Table 3. The effects of body weight and occupation on energy requirements of women

Body weight (kg)	Light activity (kcal)	Light activity (MJ)	Moderately active (kcal)	Moderately active (MJ)	Very active (kcal)	Very active (MJ	Exceptionally active (kcal)	Exceptionally active (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

Source: WHO; 1973

or other ecological factors. (Note: The Expert Committee of the FAO/WHO (1973) recommended that the energy requirements assigned to the reference man and woman should be increased by 3% for every 10 degrees C of mean annual external temperature below 10 degrees C, while the energy requirements decrease by 5% for every 10 degrees C of mean annual external temperature above the reference temperature.)

In childhood and adolescence there are additional energy needs for growth, while needs are also increased during pregnancy and lactation. The requirements of children and adolescents are based on the observed energy intakes of apparently healthy groups of persons of the specified ages and on the observed growth rates and body sizes of North American and European children. The figures given for children and adolescents do not attempt to predict the effect of activity or other variables noted for the adult.

The total energy cost of pregnancy has been estimated to be about 80.000 kcal of which about 36.000 kcal is thought to be accounted for by fat storage. The total of 80.000 kcal would require an increase of 285 kcal per day over the total period of pregnancy.

During lactating, the average breast milk production is about 850 ml/day, while the energy content is about 600 kcal. Assuming that the efficiency of energy secretion in the form of milk is 80%, the estimated energy requirement of the mother would be about 750 kcal per day. Over a period of 6 months of lactation this would amount to a total of 135.000 kcal. However, fat storage (36.000 kcal) during pregnancy will reduce the extra energy requirement to about 550 kcal per day over a 6 month period.

3.3.2. Estimation of energy requirements at the national or population level

In a population both the requirements 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. This means that individuals tend to consume energy in proportion to their own needs. A reasonably equitable distribution of energy may be expected.

The starting point for an estimation of energy requirement of a population is the requirement of the reference man and reference woman. The energy requirements of a reference man and woman, as defined by the FAO/WHO (1973), see Appendix 1, are estimated at respectively 3000 kcal (based on 46 kcal per kg body weight) and 2200 kcal (based on 40 kcal per kg body weight) per day. In the case that the population in study has body weights that are different from the reference values. it is sufficient to multiply their weight by 46 kcal for men and by 40 kcal for women. (Note: For data for average body weights for different countries see Eveleth and Tanner, 1976) These "new" reference values are the requirements for adults of 20-39 years with moderate activity. Because energy requirements differ with age, it is essential in a study to take the age distribution of the population into account. With respect to adults aged 20-39 years, the level of requirements per age group is as follows:

age group	sex	As percentage, with respect to age group 20-39
13-15	male	97
	female	113
16-19	male	102
	female	105
40-49		95
50-59		90
60-69		80
70 and over		70

In the case that the activity level differ from the moderate level, 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 factors:

activity level	correction factor, percentage of moderate activity
light activity	90
moderate active	100
very active	117
exceptionally active	134

Note: These factors apply to the various age and sex groups from 13 years onwards. Thus the energy requirements for children younger than 13 years are never corrected for a different level of activity. The activity level is assumed to be the same for all children younger than 13 years. The same procedure, no correction below 13 years, is followed for body weight. Adjustments for body weight are not made in order to allow catch-up growth. So the energy allowances for children are in general higher than necessary. An average body weight in a given population which is lower than the reference children would normally result in a lower recommendation for energy.

The last "correction" that has to be made is for pregnancy and lactation. It is convenient to include in the average energy requirements for children below the age of 1 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 that of children aged less than 12 months by 10%. The total energy supplement for pregnancy is about 240 kcal per infant per day (80.000 x 1.1: 365). The energy requirement for lactation are estimated at 750 kcal a day for 6 months and those of an infant from 6 to 12 months are estimated at 960 kcal. The energy requirements for lactation must be lowered to 550 kcal a day because of fat storage during pregnancy. If we assume that half of the infants are below 6 months, the requirements resulting from lactation and from the supplement necessary for the child during its first year of life average 755 kcal per day. In total the figure of 755 + 240 = 995 kcal per day for infants under the age of one year represent the energy allowance for infants and the supplementary needs of pregnant and lactating women.

The energy requirements of children younger than 13 years are assumed to be the same all over the world. The figures are:

age group	energy requirements (kcal)
<1	995
1-3	1360
4-6	1830
7-9	2190
10-12	2600

So, the energy requirement of a population can be calculated if the following information is present:

- average body weight of both man and woman (adult)
- age and sex distribution of the population
- activity level(s)

Appendix 3 gives an example of a calculation for a certain country.

3.4. Protein

3.4.1. Protein requirements

Dietary protein is needed:

- to replace the unavoidable (obligatory) loss of nitrogen resulting from the turnover of tissue proteins
- to provide amino-acids for the synthesis of new protein in developing tissues during growth and pregnancy and,

- to provide amino-acids for the synthesis of milk proteins during lactation.

Protein is built up by amino acids. The human body can synthesize or transform most of these amino acids as long as a suitable source of nitrogen is provided. An adult cannot synthesize eight amino acids, while an infant cannot form nine amino acids. These amino acids have been termed essential amino acids, because they must be supplied by the diet. So the diet must supply both enough protein/nitrogen (quantity) and adequate quantities of essential amino acids (quality). If a dietary protein contains too low a concentration of one of the essential amino acids, even though the protein is fed at the safe level of intake for egg or milk protein, the requirement for that amino acid would not be met.

The calculation of the body's needs for protein are based on two different approaches

(a) obligatory N losses (the amount of N found in urine, sweat, etc. when the diet contains no protein) and the amounts of N needed for the formation of new tissues

(b) nitrogen balance studies, minimum N intake needed to maintain N equilibrium in adults or satisfactory growth in children.

When the results of these two approaches are compared, it is found that even with excellent dietary proteins, such as those in egg and milk, about 30% more protein (nitrogen) is needed to maintain nitrogen balance, than the total obligatory nitrogen losses observed under conditions of no protein intake. On the grounds of these results the joint FAO/WHO Ad Hoc Expert Committee on Energy and Protein requirements (1973) concluded that even very high quality proteins are utilized with considerable less than 100% efficiency in maintaining nitrogen balance. The Expert Committee increased the obligatory losses with 30% to obtain the final values for physiological N requirements for all healthy people except infants less than 6 months of age (see Table 4 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 (they are intended to cover the needs of 97.5% of the population) an allowance is needed for individual variation. This variation (standard deviation) is estimated as approximately 15%. The average N-requirement found plus twice the standard deviation (30%) gives the so called "recommended intake" or "safe level of intake" (see Table 4 column C and D).

The factor 6.25 (Note: Proteins contain 16% nitrogen) is applied to convert safe levels of N intake to safe levels of protein intake expressed in terms of milk or egg 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 amount, 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, for instance, rice has a conversion factor of 5.95. Most food composition tables derive estimates of protein content by applying different factors (like 5.85 for rice) to the nitrogen content of individual foods. If we want to express protein as "crude protein" it is necessary to make a correction of the reported protein content. In the case of rice this correction factor will be 1.05 (1.05 x 5.95 = 6.25). These correction factors for other foodstuffs are shown in Appendix 4.

It is important to recognize the effect of growth on protein requirement. The needs of infants and young children, expressed per kilogram of body weight,

Table 4. 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]

Source: WHO; 1973

are much higher than those of older children and adults making them more vulnerable to dietary protein inadequacies.

Protein requirements are increased during pregnancy and lactation. Expressed as milk protein, the safe level of intake for pregnancy calls for the addition of about 1, 4, 8 and 9 gram of protein per day in the first, second, third and fourth quarter of pregnancy. During lactation, the requirement appears to increase by a 17 gram protein per day.

In practice, it is possible that all persons except young infants (breast feeding) consume diets with protein that are less well utilized, than are egg and milk protein. When there is no information about the protein quality of a diet, a correction for quality must be arbitrary. However, some rough guidelines to the probable relative quality of mixed diets can be given. Diets rich in animal protein, which are common in much of North America and Europe, probably have a relative protein utilization value of about 80% compared with egg and milk. In contrast diets based on a single cereal staple with few other sources of protein, such as those consumed in some parts of Asia, may have relative utilization values as low as 60%. In between are the common mixed cereal and legume diets, perhaps with small amounts of animal proteins. Such diets have a relative utilization value of about 70% (Beaton and Patwardhan, 1976). The effect of these differing utilization values on estimated protein needs is illustrated in Table 5. So in order to calculate the amounts

Table 5. 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.

Source: WHO; 1973

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. These corrections may overestimate the needs of adults but are a necessary factor for children and pregnant and lactating women.

Factors that are often mentioned as influencing protein requirements are: stress, heat, heavy work, energy intake and infection. Only the last two factors are of significant importance. Infections affect protein requirements by inducing some degree of depletion of body N during acute episodes. Because it is not possible to quantify the effects of infections on the protein needs, the protein requirements cannot be corrected by the incidence of infections. In the case that energy intake is limited dietary proteins and tissue proteins are catabolized as energy sources. In this period, increasing dietary protein without increasing energy intake may have little or no effect on tissue protein retention. It is important to realize that "protein deficiency" can be produced by either dietary protein or dietary energy restriction (Beaton and Patwardhan, 1976).

3.4.2. Estimation of protein needs at the national or population level.

As already mentioned in paragraph 3.2. protein standards are not as meaningful indicators as calories are. There is no reason to believe that available protein would be equitable distributed in proportion to the needs. As in the computation of energy needs (see paragraph 3.3.2) it is necessary to have reliable data on the average body 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. Because the number of pregnant and lactating women is mostly unknown, it is necessary to estimate this number. For this estimate it is assumed that there are 10% more pregnant women than infants below 12 months of age. In this way it is assumed that both pregnancy wastage and perinatal mortality are taken into account. If the number of lactating women is not known, it can be approximately deduced from the number of infants under 12 months of age. Because it is often impossible to get information about the length of lactation the following assumption is made: all infants below one year of age are being breast fed. Because the protein needs for lactation (17 gram/day) are higher than any substitute feeding of an infant, the figure of 17 gram in general overestimates real protein needs.

If the relative quality of the dietary protein is 60%, 70% or 80% of that of egg or milk, it is necessary to use the correction factors of respectively 1.67, 1.43, and 1.25 to calculate the safe level of protein intake.

Since protein requirements vary among different age groups in a population, the per capita 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 capita daily requirements for a population is given in Appendix 5.

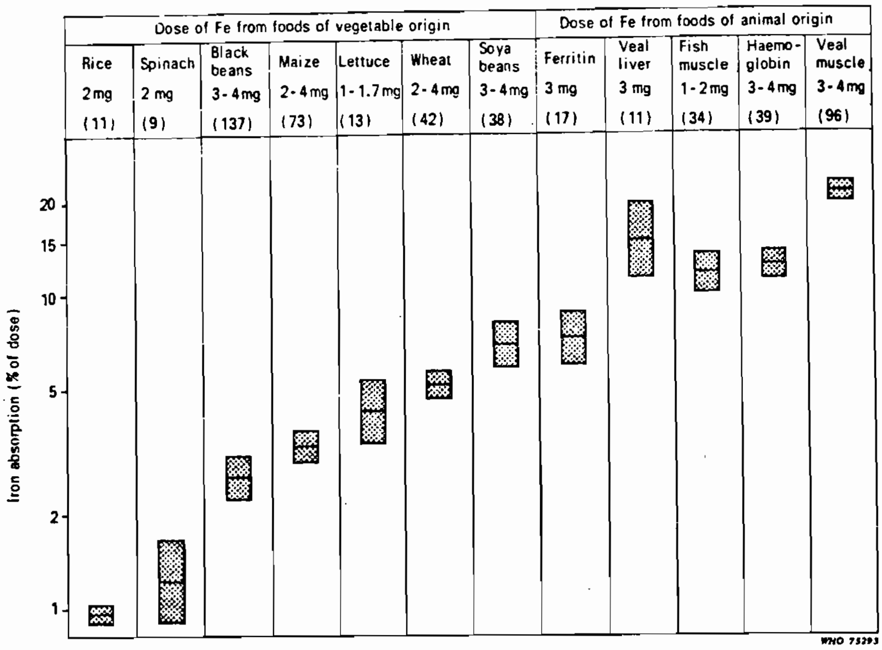
3.5. Iron Requirements

Iron absorbed from the diet must replace the physiological losses (partly through faeces, urine, skin and menstruation), maintain body stores of iron and meet the needs of growth, as in infancy, childhood and pregnancy. The iron recommendations are intended to generate and preserve iron stores rather than merely prevent anaemia.

Iron is found widely in foods of both animal and vegetable origin. The proportion of dietary iron that is actually available for absorption varies widely in different diets. In general, the bio-availability of iron is high in diets

rich in animal foods and decreases as the proportion of food of vegetable origin in the diet increases (see Figure 4).

The efficiency with which iron is absorbed from food is in general low, only 5-25% of the iron is absorbed, depending on the composition of the diet. Its availability is greatest in meat (products), less in legumes and least in cereals. Estimates of the upper limits of iron absorption that might be expected in nondepleted individuals consuming various types of diets are given in Table 6. The values are substantially higher than the average absorption figures. The FAO/WHO Joint Expert Group on requirements of ascorbic acid, vitamin D, vitamin B, Folate, and iron (Beaton and Patwardhan, 1976) adopted these figures in conjunction with estimates of the upper range of individual physiological requirements recognizing that improvement in absorption (adaptation process)



[a] The horizontal thick line represents the geometrical mean value; the shaded area indicates the limits of 1 standard error. Numbers in parentheses are numbers of cases. From a collaborative study of the departments of botany and medicine, University of Washington at Seattle, WA, USA, and the Department of Pathophysiology, Instituto Venezolano de Investigaciones Cientificas, Caracas, Venezuela.

Fig. 4. Iron absorption from food[a]

Source: LAYRISSE et. al.; 1976

Table 6. Absorption of iron from different types of diet

Type of diet	Assumed *upper limit* for iron absorption by normal individuals
Less than 10 % of energy from foods of animal origin or from soybeans	10 %
10–25 % of energy from foods of animal origin or from soybeans	15 %
More than 25 % of energy from foods of animal origin or from soybeans	20 %

Soybean is grouped with foods of animal origin owing to the high bioavailability of its iron content.

Source: BEATON and PATWARDHAN; 1976

corresponds to increase in body need (as in pregnancy) or as dietary iron intakes fall.

The individual iron requirements differ significantly with age and sex (see Table 7). The basal loss of iron by men is about 1.0 mg/day. In women the basal loss is about 0.8 mg/day (smaller body size as men). However, women also lose iron in the mensus. Expressed as the average iron loss over the whole cycle this represents about 0.5 mg/day. However, individual iron losses may be much higher. To include 95% of normal women, the iron loss would have to be set at 2.0 mg/day for menstruation alone and 2.8 mg/day for total losses (Layrisse et.al., 1976). Infants and children have lower basal losses because of the relative smaller body size. However, the rapid increases in tissue mass and blood volume occurring during early growth impose major demands for iron. In the

Table 7. Recommendations for the daily intake of iron

Age and sex	Weight (kg)	Iron (mg) b		
		A	B	C
Infants				
6-8 months	8.2	5	7	10
9-11 months	9.4	5	7	10
Children				
1-3 years	13.4	5	7	10
4-6 years	20.2	5	7	10
7-9 years	28.1	5	7	10
Adolescents, Male				
10-12 years	36.9	5	7	10
13-15 years	51.3	9	12	18
16-17 years	62.9	5	6	9
Adolescents, Female				
10-12 years	38.0	5	7	10
13-15 years	49.9	12	18	24
16-17 years	54.4	14	19	28
Adults[a]				
Reference man	65.0	5	6	9
Reference woman	55.0	14	19	28

a For description of reference man and reference woman see appendix 1

b Iron requirements are described in terms of three types of diets classified by the proportion of energy derived from animal sources or soybean:

A 25% or more
B 10-25%
C less than 10%

Source: BEATON and PATWARDHAN; 1976

older age groups, the requirements for growth gradually fall, but the increased body size increases the basal requirements. For this reason, the estimated iron requirement is relatively constant throughout childhood. It is suggested that during pregnancy and lactation it is not necessary to provide additional dietary iron, because the body possesses stores and the human body can increase the efficiency of absorption in times of increased iron need.

The interpretation of the per capita iron supplies in relation to the iron requirements needs special attention, because the iron requirement for women is much higher than for men. Although there is a clear difference in requirement it is unlikely that the iron distribution will be in accordance with these requirements. It is namely unrealistic to expect that women eat different foods from the rest of the family. Therefore, iron intake is likely to be distributed in proportion to energy intake (needs). Because women have lower energy requirements, but higher iron requirements it is predictable that women are vulnerable for iron anaemia. So the distribution of iron within the family is thus essential for the interpretation of the per capita iron supply which are based on household consumption data.

3.6. Vitamin A requirements

The intake of vitamin A varies greatly in different parts of the world. Vitamin A intakes are highest in countries where animal products are freely available and fruit is a regular component of the daily diet.

Vitamin A exists in the diet as the pre-formed vitamin (retinol or retinylestes) or as the pro-vitamin (β-carotene and other carotenoids) which can be converted to vitamin A in the body. However, while the preformed vitamin is readily absorbed and utilized, the carotenes are used very inefficiently.

Unfortunately most food composition tables do not distinguish between the various forms of vitamin A. Moreover, they describe the food content of the vitamin in terms of international units, a nomenclature that is gradually being dropped. A better, and now widely adopted nomenclature for both the vitamin A food content and requirement is the so called retinol equivalent.

1 retinol equivalent = 1 μg of retinol (free or its equivalent in ester form)
= 6 μ of β-carotene
= 12 μ of other vitamin A active carotenoids

Because most food composition tables still express the vitamin A food content in international units it is not possible to get an exact value in retinol equivalents. The total value in international units does not take into account the source. However as a rough guide, the following conversions may be applied.

(a) for animal source foods--1 I.U. of vitamin A = 0,3 retinol equivalent

(b) for plant source foods--1 I.U. of vitamin A = 0,1 retinol equivalent (Beaton and Patwardhan, 1976)

The major variables of vitamin A requirements (after taking into account the differences in sources) appear to be age, body size and growth rate (see Table 8). The vitamin A requirements of infants are very high (50-60 μ/kg body weight) compared to those of adults (12 μ/kg body weight). Because young infants depend on breast milk (or bottle milk) as a vitamin A source and they have to build up liver stores the vitamin A recommendation for lactating women are set on a higher level.

The average intake of vitamin A over extended periods is more important than the intake on a particular day, because liver stores are normally high enough to prevent clinical signs of xerophthalmia for about one year.

4. FOOD SOURCES OF NUTRIENTS

Carbohydrate and fat supply approximately 85% of the total energy requirements, while protein (and alcohol) supply the rest. Carbohydrate, fat, protein and ethanol can all act as sources of energy for the body and are interchangable in terms of energy within wide limits. Carbohydrates are the main source of energy. They come almost entirely from plants and are in general the cheapest energy source. The most important sources of carbohydrates are cereals and

Table 8. Recommendations for the daily intake of vitamin A

Age and sex	Weight (kg)	Vitamin A (μg)[b]
Infants		
6-8 months	8.2	300
9-11 months	9.4	300
Children		
1-3 years	13.4	250
4-6 years	20.2	300
7-9 years	28.1	400
Adolescents, Male		
10-12 years	36.9	575
13-15 years	51.3	725
16-17 years	62.9	750
Adolescents, Female		
10-12 years	38.0	575
13-15 years	49.9	725
16-17 years	54.4	750
Adults[a]		
Reference man	65.0	750
Reference woman	55.0	750
During last half of pregnancy		750
During first 6 months of lactation		1,200

a For description of reference man and reference woman see appendix 1

b Expressed as retinol

Source: BEATON and PATWARDHAN; 1976

roots. Fats can be divided into visible fats (oils, butter, margarine, etc.) and invisible fats (in meat, dairy products, eggs, etc.). Another very often used terminology is: separated and unseparated fats. Fats are in general more expensive than carbohydrates.

Animal products are the richest sources of protein, ranging from 12% to 30% of protein. The quality (based on amino acid composition) of animal products in general is much better than protein of plant origin. Although it is easier to obtain an adequate protein intake from animal products, it is possible to get an adequate protein supply from only plants products. In this latter case an individual should eat a variety of plants with complementary amino acids to get a correct supply of amino acids. Cereals, cereal products and legumes are satisfactory sources of protein.

Both energy and protein are indicators for the nutritional sufficiency of a diet. In general it can be said that whenever energy and protein intakes are adequate, the intake of other nutrients is also adequate. Foods rich in protein and energy are in general also good sources of other nutrients. Another general rule that is often used is: Whenever the energy intake is adequate, the intake of protein will be adequate too. Exceptions to this last rule are countries or individuals that use staple commodities that are either low in protein content or/and have a very low quality. Examples of these staples are cassava and sago. Where staples are of marginal quality, infants and children, who need more protein per unit of body weight are most seriously affected.

Iron is widely distributed in all kinds of foodstuffs. As seen in paragraph 3.5 the availability of iron differs significantly between different foods. In general it can be said that iron from animal products has the highest availability. Meat or meat products are an important iron source because it contains a relatively large amount of iron which is good available to the human body. Whole grain cereals are rich in iron but the availability of this iron is relatively low. When making statements about the iron sources it is necessary to take both the quantity as well as the quality/availability into account.

The best sources of preformed vitamin A (retinol) are liver, milk butter, cheese and egg yolk. Thus the form of vitamin A that is directly usable by the body exists only in animal products. The body can however synthesize usable vitamin A from carotene, a group of yellow and orange pigments widely distributed in fruits and vegetables. Carrots, dark green leafy vegetables and fruits are good sources of carotene. As shown in paragraph 3.6 Vitamin A (retinol) from animal sources have a higher activity (based on weight or international units) than vitamin A (carotenoids) from plant origin.

5. INCOME LEVEL AND THE CONSUMPTION OF FOODS

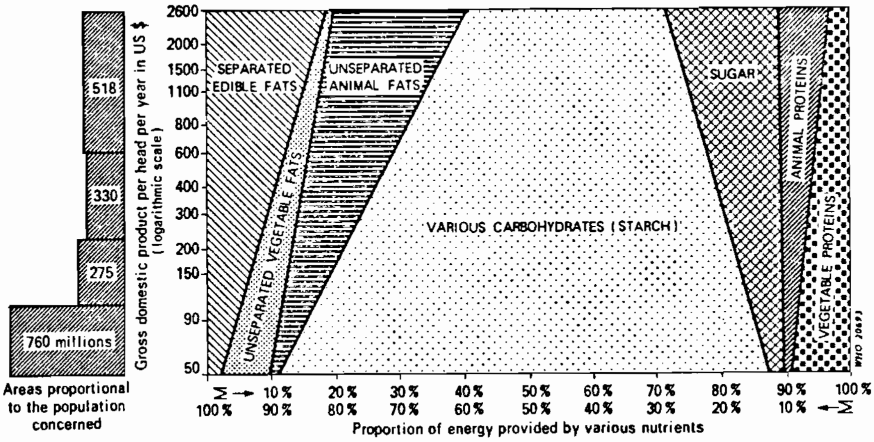
The nature and quantity of food available to a family is greatly dependent on socio-economic variables such as wealth, income and employment.

In developing countries, where the poor spend a high proportion of their income on food, more money generally means a better diet. The poor usually spend a big portion of any increase in income they receive on additional food. The percentage of another "dollar" to spend, that will be spent on food declines as total income increases. Income levels also establish a pattern for what foods are purchased with that additional "dollar". The poor spend most of it on food grains, the rich do much less so. Thus income is a major determinant of the quantity and quality of the diet.

A progressive increase in income per person generally results in increased consumption of foods such as meats, dairy products, fruits, vegetables and sugar. Because most of these foods are nutritionally desirable an improved diet is to some extent selected "spontaneously" by consumers as income rises (Willet, 1973). Income rise is of course no guarantee that this will lead automatically to an adequate diet. Incomes rise slowly for the poor and increased purchasing power often cannot overcome certain food habits and practices that stand in the way of effective nutritional improvements, especially for small children (Berg, 1973). Despite these limitations it is still interesting to investigate what the general dietary changes are when income rises. For this purpose two kinds of data are used namely:

- gross domestic product per capita related to the nutritional average diet (Perisse, et al, 1969)
- food consumption of rural households split up by income groups (Williamson and Shah, 1981)

Figure 5 gives the relation between the average income (GDP



Correlation based on 85 countries.

Fig. 5. Calories derived from fats, carbohydrate, proteins as percent of total calories according to the income of the countries

Source: PÈRISSÉ et. al; 1969

per capita and the national average diets (from food balances)). The diets were analyzed to obtain estimates of calories supplied by fats, oils, carbohydrates and proteins (animal and vegetable). It is obvious that these figures gives only very crude information about the dietary changes that occur when income rises.

The proportion of total calories supplied by carbohydrates decreases as per capita income rises, declining from 75% in those countries with per capita incomes of 100 dollars to 60% with incomes of 600 dollars and to 50% with incomes of 2600 dollars (Willet 1973). This change is due to a decline in polysaccharides (from among other cereals and roots). Although the calories supplied by polysaccharides are declining, the calories supplied by disaccharides (sugar) and monosaccharides increases when income rises. The proportion of calories supplied by fats rises steeply with per capita income from a level of 15% of total calories in those countries with per capita incomes of 100 dollars it rises to about 30% with incomes of 600 dollars and to about 40% where incomes reach 2600 dollars (Willet, 1976). Both the consumption of separated and unseparated fats from animal products is increasing, while the consumption of unseparated plants fats and oils is decreasing with income rise. The proportion of calories supplied by total protein does not change significantly with income (note: the absolute intake of protein increases with income rise). The proportion of calories supplied by animal protein rises from about 2% with incomes of 100 dollars to more than 8% when incomes reach 2600 dollars.

There are of course deviations from this general pattern. Countries of Asia with rice based diets have a fat intake that is apparently lower on the average, than other developing countries with the same GDP.

In general it can be said that an income rise in developing countries will improve the diets. By making this statement it has to be recognized that the problems that arise with affluence (obesity, cardiovascular diseases, etc.) are not taken into account. The increase in consumption of animal protein means in general a qualitative improvement in the diet. Animal protein is of a higher quality than protein from plants. Animal products are good sources of iron and vitamin A. The availability of iron is better in animal products while Vitamin A is present in the performed vitamin A form, which has a higher activity (based on IU) than vitamin A in plant products. Nutritional adequacy is thus more easily achieved if the diets includes at least small amounts of foods of animal origin.

However, the improvement in protein intake occurs very slowly, both because income increases come slowly and also because there is a rising demand for sugar, fats and oils, when incomes increase.

In developing countries, which have a low average calorie intake the demand for staple foods like cereals and roots, will be high, because these foods can fill the calorie deficits at the lowest costs. Although the elasticity of the demand for these staple foods is moderate, the quantities consumed to which they relate, constitutes a very large part of the food intake. The demand for calories from staples will decline slightly in relative terms as staples will decline slightly in relative terms as a percentage of total calories, but the demand will increase in absolute terms. The demand for vegetables, fruits, fats and oils, sugar and food of animal origin is significantly more elastic than the demand for staple foods but their initial proportions in the diet are too small to result in a nutritional restructuring of the diet (Perisse, 1979).

The same changes in the consumption pattern that are described above can be seen in Kenya (see Table 9). These data are based on rural households. (Williamson and Shah, 1981). The rise in income is mainly caused by an increase in own produced products. Own produced maize, milk (eventually english potatoes) and purchased grains, flour and roots are increasing steeply with income rise. The consumption of the other products like fats and meat increase more slowly than the staple foods and milk. The steep increase of milk consumption can be explained by the increased ownership of livestock (note: milk is an own produced commodity, see Table 9). In Kenya livestock has a very high status and expresses the level of wealth, but milk producing cattle is also a means of overcoming seasonal food shortages. Milk as cassava and sago are security foods.

These foods provide "security" to a family, allowing them to feel that they can survive a short period of shortage without necessarily having to become indebted. Because milk is more expensive than, for instance, cassava it will not (or only in small quantities) be consumed by low income groups.

Where substitution of one commodity for another occurs, because of changes in price relationships, the impact on total food demand expressed in calories or protein is likely to be small. The substitutions will take place on grounds of the attributes the particular commodity has, for instance staple food or security.

Income rise does of course not only effect the consumption pattern but also other variables like housing, education and so on. Factors that are different for low and high income groups and that have an impact on the calorie requirements as well, can either increase or decrease the per capita calorie requirements. Per capita calorie requirements of low income groups may be less than average because:

Table 9. Consumption (in K.Shs.) of foods by rural households in Kenya split up by income group

	Total mean consumption (K.Shs) per household						
Item	1611	2165	2721	3364	3892	5618	6505
Own produced commodities							
Maize	147	213	327	317	418	546	980
Millet	8	14	13	16	20	45	13
Sorghum	37	39	31	35	70	28	65
Beans	56	94	125	157	196	320	353
Eng. potatoes	13	21	92	148	129	363	221
Other crops	75	122	108	135	151	246	309
Beef	27	31	13	8	24	19	46
Other meat and poultry	38	74	83	92	109	161	161
Milk	59	141	177	285	369	534	798
Purchased commodities							
Dairy products and eggs	26	32	46	60	49	46	66
Grains, flour and root crops	335	385	452	610	491	757	580
Meat and fish	158	177	202	239	267	312	379
Fats and oils	28	52	60	84	94	135	154
Sugar and sweets	83	115	154	184	203	230	276
Fruits and vegetables	48	71	78	122	108	130	98
Drinks and beverages	86	95	122	139	141	199	252
Salt and other flavourings	22	29	36	41	33	45	43
Total consumption of own products	458	751	968	1193	1487	2262	2946
Total consumption of purchased food	786	956	1151	1478	1385	1853	1849

Source: WILLIAMSON and SHAH; 1981

(a) Their body weights are usually lower as a consequence of undernutrition during childhood, and, therefore, they require less for maintenance

(b) they have less opportunity for physical activity (insufficient demand for their labour)

(c) they have a higher ratio of children to adults.

In turn, it is suggested that calorie requirements of low income groups may be higher than average, because:

(a) they engage in occupations which require more physical exertion

(b) their household chores are more labour intensive

(c) they incur more pregnancies and do more breast feeding

(d) the ratio of young and middle-aged to old adults is higher

(e) They are subjected to more infectious diseases and parasites which impare calorie absorption.

(f) their productivity is depressed by insufficient energy due to undernutrition (Reutlinger, and Alderman, 1980). Most of these factors are taken into account when the energy requirements are calculated as described in paragraph 3.3.2. The other factors, like diseases, are not quantifiable and thereby cannot be taken into account.

6. CONCLUSIONS

The most important public health problems in the tropics are protein-energy malnutrition, iron deficiency and vitamin A deficiency. These three nutritional diseases can occur on their own but are most of the time interrelated with each other. There is a close relation between the occurrance of protein-energy malnutrition and vitamin A and iron deficiency.

Infants and young children are the most vulnerable groups to protein-energy malnutrition. Vulnerable to iron deficiency are young children (6 - 18 months) and menstrating and pregnant women, while children and infants are very vulnerable to vitamin A deficiency. So young children are, from the physiological point of view, vulnerable to the three most important nutritional diseases of the tropics.

Energy recommendations are average values for healthy persons in a given age/sex/activity group, while recommendations for other nutrients are estimates of the upper range of individual requirements.

Nutrient recommendations should never be used as a sole basis for the evolution of nutritional status of a person, group or country. Although nutritional standards have big shortcomings, they can serve as guidelines or goals for population groups, provided their limitations are recognized. The most often used and relatively the best indicator of the extent of nutritional inadequacies is energy-intake. The reason for this is that energy allowances are rigid and that energy deficiency is often associated with insufficient intake of specific nutrients. In general it can be said that whenever the energy intake is adequate, the intake of protein and other nutrients will be adequate too. Of course there are many exceptions to this general rule, especially when the staple foods which are used are of a low quality.

The energy "requirement" of a population can be calculated if information is available over the:

- average body weight of both men and women
- age and sex distribution of the population
- activity level(s)

In general it can be said that an income rise in developing countries will improve the diet in both quantity and quality. An income rise is of course no guarantee that this will lead automatically to an adequate diet. Nutrient adequacy is more easily achieved if the diet includes foods of animal origin. Animal protein is of a higher quality than plant protein. Iron availability is better in animal products, while vitamin A is present in the preformed vitamin A form, which has a higher activity than vitamin A in plant products.

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Definition of a 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, similary healthy, and weighs 55 kg. She may be engaged for 8 hours in general household work, in light industry, or in other moderate 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.

Source: WHO; 1973

APPENDIX 2

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

Source: WHO; 1973

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

Source: WHO; 1973

APPENDIX 3

Example of a calculation of the energy requirements for a certain country

Age groups (years)	Individual requirements (kcal)	Adjustment according to weight and age	Population distribution (%)	Contribution to total requirements per 100 persons	Correction factors for activity	Adjustment according to activity
Children						
0- 1	995	995	3.56	3,542		3,542
1- 3	1360	1360	10.61	14,430		14,430
4- 6	1830	1830	9.64	17,641		17,641
7- 9	2190	2190	9.12	19,973		19,973
Male adol. and adults						
10-12	2600	2600	3.40	8,840		8,840
13-15	0.97 x M	2231	3.40	7,585		7,585
16-19	1.02 x M	2346	5.59	13,114	1.119	14,675
20-39	M	2300	13.32	30,636	1.119	34,282
40-49	0.95 x M	2185	4.00	8,740	1.119	9,780
50-59	0.90 x M	2070	2.77	5,734	1.119	6,416
60-69	0.80 x M	1840	1.55	2,852		2,852
70+	0.70 x M	1610	0.68	1,095		1,095
Female adol. and adults						
10-12	2350	2350	3.22	7,567		7,567
13-15	1.13 x F	2034	3.22	6,550		6,550
16-19	1.05 x F	1890	5.23	9,885	1.085	10,725
20-39	F	1800	12.46	22,428	1.085	24,334
40-49	0.95 x F	1710	3.81	6,515	1.018	6,632
50-59	0.90 x F	1620	2.39	3,872	1.018	3,942
60-69	0.80 x F	1440	1.34	1,930		1,930
70+	0.70 x F	1260	0.65	819		819
					Total	203,610
					per caput	2,036

Data used for this example:

The average body weights for men and women are respectively 50 kg and 45 kg, while the energy requirement per kg body weight are respectively 46 kcal and 40 kcal. So the energy requirement for an adult man of 20-39 years is 2300 kcal per day, while the energy requirement for an adult woman of 20-39 years is 1800 kcal per day.

The age and sex distribution of the population is given in the fourth colum of the table.

The activity levels for men are:
In the age groups 16-19, 20-39, 40-49 and 50-59 70% are very active
and for women:
In the age groups 16-19 and 20-39 50% is very active
In the age groups 40-49 and 50-59 25% is very active, while 25% has light activity and the rest (50%) is moderate active

APPENDIX 4

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*: Whole seed, except hulls and groats; Pearled, light or dark. *Oats*: Oatmeal, rolled oats	5.83	1.07
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

Source: WHO; 1973

APPENDIX 5

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.

[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).

Source: WHO; 1973