Pinguiculae are intra-conjunctival, while Bitot's spots are epithelial in origin and are superficial plaques lying on the conjunctiva.

Pterygium (Fig. 10). This lesion, so-called because of its wing-shaped appearance, is produced by a fleshy double fold of conjunctiva, growing progressively laterally across the cornea. Its cause is unknown, but appears to be related to prolonged irritation, as from sun-glare. It has no nutritional significance.

Pannus. This is a characteristic lesion of infection of the cornea with the trachoma virus. It is due to invasion of the cornea by blood vessels and infiltration. If advanced, it has the clinical appearance of a superficial opacity of the cornea, especially in its upper part. In early cases, vessels which are always present can be seen only with a biomicroscope.

4. Lips

Group 1

Angular stomatitis (Plate II C). The term is used to describe soaked and exoriated lesions associated with fissuring at the angles of the mouth. The fissures may be shallow or deep, confined to a small area of the angles of the mouth or extending into the buccal cavity and a few millimetres onto the skin outside. Milder lesions are discerned more easily with the mouth half open. The sign should be reported as positive only if both angles of the mouth are involved.

Angular scars. Healed angular stomatitis may result in pink or blanched scars at the angles of the mouth, depending on the interval since the acute episode. In older children, the possibility of the scars being healed rhagades of congenital syphilis requires consideration.

Cheilosis (Fig. 11). This lesion is characterized by vertical fissuring, later complicated by redness, swelling and ulceration of the lips, other than the angles. The centre of the lower lip is most usually affected. Climatic factors, such as cold and wind, may sometimes be responsible.

Group 2

Chronic depigmentation of the lower lip. This is usually central and may, in some cases, represent the site of an old, healed cheilosis.

5. Tongue

Signs in the mouth affecting the tongue or gums must be considered in relation to local trauma, as from spicy foods and false teeth, as well as to nutritional deficiency.

Group 1

Oedema of tongue. This can be detected by the indentations made by pressure of teeth along the edges of the tongue.
FIG. 11. CHEILOSIS

FIG. 12. HYPERTROPHIC PAPILLAE
Scarlet and raw tongue. The tongue is bright red in colour, usually of normal size or slightly atrophic, denuded and very painful.

Magenta tongue. The tongue is purplish red in colour; numerous morphological changes may co-exist.

Atrophic papillae (Plate III A). The filiform papillae have disappeared, giving the tongue an extremely smooth appearance. The distribution may be central or marginal. Permanent records of the lesion can be made with ‘tongue prints’, although this is rarely practicable or necessary.

Group 2

Hyperaemic and hypertrophic papillae (Fig. 12). The papillae are hypertrophic and red or pink, and give the tongue a granular or pebbly appearance (red strawberry).

Fissures (Plate III B). Cracks on the surface of the tongue with no papillae on their sides or floors. These must not be confused with the congenital ridging and convoluted appearance known as ‘scrotal tongue’, which has no nutritional significance.

Geographic tongue. The tongue has irregularly distributed patchy areas of denudation and atrophy of epithelium. It is painless and symptomless. Its etiology is obscure and no treatment appears to be effective.

Pigmented tongue. Punctate or patchy areas of blue-black mucosal pigmentation are present, sometimes associated with similar patches on the gums. Present evidence suggests that they are of no significance (Raper, 1948).

6. Teeth

Group 1

Mottled enamel (Plate III C and D; Fig. 13). The teeth are mottled with white and brownish patches, with or without erosion or pitting of the enamel, usually best seen in the upper incisors. Various other conditions, genetic and of other etiologies, can also produce mottling, and the differential diagnosis between mild fluorosis and non-fluoride opacities has been given by Russell (1961) (Table 2) and by Dean (1934, 1942).

Group 2

Caries. The presence of decayed, missing or filled teeth (DMF) is often used to record the amount of caries present in a community, although teeth may be missing for other reasons, including chronic pyorrhoea, trauma, or—in parts of rural Africa—removal because of local custom.

1 Details of methods and techniques for specialist dental surveys are given in the report of the WHO Expert Committee on Dental Health (1962).
TABLE 2. DIFFERENTIAL DIAGNOSIS: MILD FORMS OF DENTAL FLUOROSIS (QUESTIONABLE, VERY MILD, AND MILD) AND NON-FLUORIDE OPACITIES OF ENAMEL*  

<table>
<thead>
<tr>
<th></th>
<th>Milder forms of fluorosis</th>
<th>Non-fluoride enamel opacities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area affected</td>
<td>Usually seen on or near tips of cusps or incisal edges</td>
<td>Usually centred on smooth surface; may affect entire crown</td>
</tr>
<tr>
<td>Shape of lesion</td>
<td>Resembles line shading in pencil sketch; lines follow incremental lines in enamel, form irregular caps on cusps</td>
<td>Often round or oval</td>
</tr>
<tr>
<td>Demarcation</td>
<td>Shades off imperceptibly into surrounding normal enamel</td>
<td>Clearly differentiated from adjacent normal enamel</td>
</tr>
<tr>
<td>Colour</td>
<td>Slightly more opaque than normal enamel; “paper-white.” Incisal edges, tips of cusps may have frosted appearance. Does not show stain at time of eruption (in these milder degrees, rarely at any time)</td>
<td>Usually pigmented at time of eruption; often creamy-yellow to dark reddish-orange</td>
</tr>
<tr>
<td>Teeth affected</td>
<td>Most frequent on teeth that calcify slowly (cuspids, bicuspids, second and third molars). Rare on lower incisors. Usually seen on six or eight homologous teeth. Extremely rare in deciduous teeth</td>
<td>Any tooth may be affected. Frequent on labial surfaces of lower incisors. May occur singly. Usually one to three teeth affected. Common in deciduous teeth</td>
</tr>
<tr>
<td>Gross hypoplasia</td>
<td>None. Pitting of enamel does not occur in the milder forms. Enamel surface has glazed appearance, is smooth to point of explorer</td>
<td>Absent to severe. Enamel surface may seem etched, be rough to explorer</td>
</tr>
<tr>
<td>Detection</td>
<td>Often invisible under strong light; most easily detected by line of sight tangential to tooth crown</td>
<td>Seen most easily under strong light on line of sight perpendicular to tooth surface</td>
</tr>
</tbody>
</table>

* Reproduced by permission from Russell (1961).

In children in most tropical areas with inadequate dental services, only the presence of decayed teeth with cavities can be recorded. The method of examination must also be noted. This will usually be by inspection alone.

The prevalence of caries is suggested by the percentage of the adult population with one or more teeth decayed or missing or filled (DMF), or, in the case of children, of those with one or more teeth decayed or filled (DF). The intensity of caries in a community is calculated by the average number of DMF teeth per person.

While malnutrition in the pregnant woman plays a part in the etiology of caries in the first dentition, caries in both deciduous and permanent teeth is more related to local effects of the foods consumed, especially to the dietary content and frequency of ingestion of sugar, over-milled flour and other highly refined carbohydrate foods.

Attrition (Fig. 14). The cutting borders of incisors and molars may be worn down and flattened. This seems related principally to the toughness
of the diet, especially its content of hard foods requiring prolonged mastication.

Enamel hypoplasia (Fig. 15). Defective formation is usually generalized over the tooth surface, especially the medial third.

Enamel erosion (Fig. 15). The term describes the sharply defined areas, usually around the gum margin, where the tooth enamel has become eroded.

7. Gums

Group 1

Spongy, bleeding gums (Plate IV A). Purplish or red spongy swelling of the interdental papillae and/or the gum margins, which usually bleed easily on slight pressure.

This sign can occur with chronic intoxication with certain drugs, especially hydantoinates. It is absent even in cases of severe lack of ascorbic acid in young children (infantile scurvy) until the teeth have erupted.

Group 2

Recession of gums. Atrophy and recession of the gums occur sometimes, exposing the roots of the teeth. This is usually secondary to pyorrhoea.

Group 3

Pyorrhoea (Plate IV B). Suppuration of gum margins, which are red and bleed easily with no hypertrophy.

8. Glands

Group 1

Thyroid enlargement (Fig. 16-19). The gland is visibly and palpably enlarged. The enlargement may be diffuse or nodular. Inspection and palpation while the subject swallows may be helpful in diagnosis.

For more specialized endemic goitre surveys, the technique and classification of Perez, Scrimshaw & Munoz (1960) should be followed. In this classification, three grades are recognized:

(a) Grade 1—persons with palpable goitres. The thyroid is probably enlarged more than four to five times, although not visible with the head in the normal position. Most cases will be readily visible with the head thrown back and the neck fully extended (Fig. 17). Palpation is carried out by the

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**FIG. 16. TECHNIQUE USED IN EXAMINATION OF THYROID GLANDS**

**FIG. 17. GROUP 1 THYROID GLAND**

**FIG. 18. GROUP 2 THYROID GLAND**

**FIG. 19. GROUP 3 THYROID GLAND**
examiner sitting or standing facing the subject and placing his thumbs gently on either side of the thyroid area (Fig. 16).

(b) Grade 2—persons with visible goitres. Goitres in this category (Fig. 18) are easily visible with the head in the normal position; they are, however, smaller than those in Grade 3.

(c) Grade 3—persons with very large goitres. Goitres in this category can be recognized at a distance (Fig. 19). They are grossly disfiguring and may be of such a size as to cause mechanical difficulties with respiration and with the wearing of clothes.

Parotid enlargement (Fig. 20). This sign is positive if there is a chronic, visible, non-inflammatory, bilateral swelling of the parotids. The glands are firm, non-tender and painless. The overlying skin is unchanged. If the swelling is marked, the lobules of the ears are hidden when the subject is viewed from the front. It is most usually seen in schoolchildren and adults.

Parotid enlargement is usually recorded as only positive, without grading according to size. If grading is required, the technique of Shaper (personal communication, 1965) may be used (Fig. 21).

FIG. 20. PAROTID ENLARGEMENT

FIG. 21. MEASUREMENT OF PAROTID ENLARGEMENT
(SHAPER—PERSONAL COMMUNICATION, 1965)
Group 2

Gynaecomastia. Bilateral, visible and palpable enlargement of the nipple and glandular subareolar breast tissue in males.

9. Skin

Group 1

Xerosis. Generalized dryness with branny desquamation. Factors to be considered when interpreting this and other skin signs are environmental, such as dirt, lack of washing, a dry, hot, windy climate, and the habitual use of oil on the body, and, more rarely, genetic, as in the case of the uncommon condition, congenital ichthyosis.

Follicular hyperkeratosis (Fig. 22). Two clinical types are recognized:

(a) Type 1, in which the lesion consists of hyperkeratosis surrounding the mouths of hair follicles and forming plaques that resemble spines. It is readily detected by the spiky feeling it gives when the palm is passed over an area of affected skin. Its characteristic distribution is frequently confined to the buttocks, thighs and especially the extensor aspects of the legs and arms, particularly the elbows and knees. The surrounding skin is dry and lacks the usual amount of moisture and oiliness. In early literature on the subject, the condition was termed “phrynoderma” (toad skin).

(b) Type 2, in which the lesions have a similar appearance, but the mouths of the hair follicles contain blood or pigment. The intervening skin is not unusually dry. The condition is seen mostly in adults. The distribution is usually over the abdomen and the extensor aspects of the thighs.

Petechiae. Small haemorrhagic spots in the skin or mucous membranes. Application of a blood pressure tourniquet may sometimes produce additional petechiae.

Pellagrous dermatosis (Fig. 23 (a) and (b); Plate IV C and D). Typical pellagrous skin lesions are symmetrical, clearly demarcated, hyperpigmented areas with or without exfoliation. The lesions are common in parts of the body exposed to sunlight, including the cheeks and the forearms; when they appear around the neck the condition is called “Casal’s necklace”.

In acute cases, the skin is red, slightly swollen and may show vesiculation, exudation and cracking. The lesion itches and burns. In chronic cases, the dermatosis occurs as a roughening and thickening of the skin with dryness, scaling and brown pigmentation.

Flaky-paint dermatosis (Fig. 24 (a) and (b)). Extensive, often bilateral hyperpigmented patches of skin which desquamate to leave hypopigmented skin or superficial ulceration, often resembling a second-degree burn. It can occur anywhere, but characteristically on the buttocks and the back of the thighs. The lesion was once termed “crazy-pavement dermatosis”.

DIRECT ASSESSMENT OF HUMAN GROUPS 33
FIG. 22. FOLLICULAR HYPERKERATOSIS

FIG. 23. PELLAGROUS DERMATOSIS
(a) Both forearms and hands
(b) Face and neck (Casal's necklace)
FIG. 24. FLAKY-PAINT RASH
(a) Forearms

(b) Backs of legs

FIG. 25. SCROTAL DERMATOSIS
Scrotal and vulval dermatosis (Fig. 25). A desquamating lesion of the skin of the scrotum or vulva, often highly itchy. Secondary infection may supervene.

Group 2

Mosaic dermatosis. Large mosaic plaques, firmly adherent in the centre, but showing a tendency to peel at the periphery, present bilaterally on both shins.

Thickening and pigmentation of pressure points. Diffuse thickening, with pigmentation of the pressure points, such as the knees, elbows and front and back of the ankles. The knuckles may also be involved. The affected areas may be wrinkled, with or without fissuring.

Intertriginous lesions. Raw, red and macerated lesions in the skin flexures prone to constant friction, such as groins, buttocks and axillary folds, which frequently become secondarily infected.

10. Nails

Group 1


Slightly spoon-shaped nails can be found commonly, affecting the toenails only, in barefooted communities; the condition appears to have no significance.

Group 2

Transverse ridging or grooving of nails.\(^1\) This should be recorded if present in nails of more than one extremity.

11. Subcutaneous tissues

Group 1

Oedema. Usually first apparent over the ankles and feet, it may extend to other areas of the extremities. It may involve the genitals, face and hands. In early stages, it can be detected by firm pressure for three seconds with one digit on the lower portion of the medial surface of the tibia. The sign is taken as positive if there is a visible and palpable pit that persists after the pressure is removed. It is recorded only if present bilaterally.

Subcutaneous fat. An approximate estimate of any increase or decrease can be gauged by palpation of a skin-fold. If possible, detailed measurements with skin-fold calipers should also be made (see page 72).

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\(^1\) Other nail changes have been suggested as signs of malnutrition, including paired transverse lines (Mufheche, 1956) and dark brown or black bands running longitudinally (Bisht & Singh, 1962). They require further investigation. A study in South Africa did not find any association between Mufheche's lines and kwashiorkor (Cazel & Basson, 1956). Mottled nails have been described as occurring in fluorosis (Grech & Latham, 1964).
12. Muscular and skeletal systems

Group 1

Muscular wasting. This can be detected by observation and palpation of the upper arm, especially the biceps. Measurement of muscle should be carried out wherever relevant.

In children particularly, muscle wasting, accompanied by hypotonia, can result in pot-belly, lordosis and a winged appearance of the scapulae.

In severely affected children with protein-calorie malnutrition, including kwashiorkor, the degree of muscle wasting can be roughly assessed by testing the child’s ability to hold up his head when pulled gently from a lying to a sitting position (Smythe, 1958).

Craniotabes. This sign consists of areas of softening of the skull, usually involving the occipital and parietal bones. Affected areas dent on pressure and spring back after the pressure is removed. The sign is positive only in infancy.

Frontal and parietal bossing. Localized thickening and heaping up of the frontal and parietal bones of the skull. Bossing may have a nutritional cause, but it can also occur in children of African ancestry with sickle-cell anaemia and appears to be recognized by some communities as a possibly familial characteristic.

Persistently open anterior fontanelle. This may be defined as an anterior fontanelle which is open on palpation after the age of eighteen months.

The sign is not specific and can be found in hydrocephalus and other conditions.

Epiphyseal enlargement (Fig. 26). Enlargement of the epiphyseal ends of long bones, particularly affecting the radius and ulna at the level of the wrist, and the tibia and fibula at the level of the ankle. In the assessment of this sign, allowance must be made for the degree of subcutaneous fat present. In wasted persons, the ends of the long bones appear unusually prominent.

Beading of the ribs (Fig. 27). A symmetrical nodular enlargement of the costo-chondral junctions, producing a “rosary” effect. It is essentially a special localized form of epiphyseal enlargement.

Knock-knees.

Bow-legs (Fig. 28).

Diffuse or local pelvic skeletal deformities.

Deformities of the thorax. The two most important are Harrison’s sulcus (Fig. 29)—an indentation running laterally around both sides of the chest—and pigeon chest. However, many common thoracic deformities are unrelated to malnutrition (e.g., funnel chest, Fig. 30).
FIG. 26. EPiphyseal Enlargement

FIG. 27. RICKETY ROSARY
Musculo-skeletal haemorrhages. Larger haemorrhages may occur as (a) intramuscular haematoma, usually of the calf or thigh, (b) haemarthrosis, (c) subperiosteal haemorrhage. These may be suspected clinically, but can be confirmed only by detailed clinical examination and by special tests, such as aspiration for haemarthrosis, and radiology for subperiosteal haemorrhage.

13. Internal systems

GASTRO-INTESTINAL SYSTEM

Group 1

Hepatomegaly. The abdomen should be palpated in a standard position, that is, with the subject lying down, with the hips and knees flexed, if it is intended to measure the exact size. This can be recorded in centimetres below the costal margin.¹

In the case of a young child, if the exact size is not to be recorded, examination can be carried out with the child reclining on the mother’s lap, which reduces the likelihood of struggling. In any case, the position at examination should be noted.

Hepatomegaly in young children can occur solely as a result of a low protein, largely carbohydrate diet. It is particularly common in the West Indies. However, the enlarged palpable livers found in young children in many tropical regions appear to have mixed etiologies, including chronic malaria, malnutrition and possibly the result of the migration of helminth larvae through the liver.

NERVOUS SYSTEM

Psychomotor change. Listlessness can occur at any age, but is most strikingly seen in severe protein-calorie malnutrition of early childhood (see Fig. 49). This is especially so in kwashiorkor, when the child is apathetic, withdrawn and lacking in liveliness and interest in his surroundings. It is difficult to measure exactly, but can be crudely tested by watching the reaction to a brightly coloured object or light.

Mental confusion (Fig. 31). This may include psychosis.

Clinical tests of the central nervous system may include sensory loss, motor weakness, loss of position sense, loss of vibration sense, loss of ankle or knee jerks, and calf tenderness.

These tests are extremely difficult to carry out with any accuracy under field conditions. Even in hospital the problem of obtaining accurate, repeatable results with knee and ankle jerks is well recognized. With

¹ Precise studies of liver enlargement in young children can be undertaken by averaging the size of the liver found by palpating the abdomen in the mid-line and in the nipple-line (“average palpable liver size”) (Oomen, 1957a).
apprehensive subjects hastily examined in rural survey, it is even more difficult, especially when testing for calf tenderness and vibration sense. From the practical viewpoint, the tendon jerks should always be reinforced, tested in two positions and verified by a second examiner. Only absolute and bilateral loss should be reported (ICNND, 1961c).

If required, vibration sense can be tested with a tuning fork of 128 vibrations per minute (ICNND, 1963). Motor weakness in adults is classically judged by the “squatting” test—that is, the ability to squat and rise four times successively.

Subjective symptoms suggestive of possible neurological involvement, such as paraesthesia, are even less reliable, and, on the whole, history-taking in nutrition prevalence surveys in developing regions is of limited value, owing to the many problems of language, cultural interpretations and witness reliability.

CARDIOVASCULAR SYSTEM

Group 1

Cardiac enlargement. The simplest test of value in survey work is an examination by palpation to assess the presence of cardiac enlargement. However, with the practical exceptions of anaemia and beriberi, causes of cardiomegaly are essentially non-nutritional.

Tachycardia. The resting pulse rate may be of value in a nutritional status survey, because tachycardia can occur in anaemia, beriberi and certain probably nutritional cardiopathies. The rate must always be compared with “normal” values for the appropriate age-group. It will, of course, be very difficult to obtain a resting pulse under survey conditions. If felt to be of importance, a sample of those attending can be rested and examined, but usually this will be neither practicable nor worthwhile.

Group 2

Blood pressure. If the blood pressure is taken, the technique employed must be carefully standardized.
Interpretation of Signs in Relation to Nutrient Deficiencies

The concept of the "key sign", introduced by Jolliffe et al. (1958), was based on the association of a certain sign with a given nutrient deficiency, such as angular stomatitis and riboflavin lack. With few exceptions—for example, thyroid enlargement and iodine deficiency—this concept is no longer regarded as valid, because of the lack of specificity of the signs recorded and because it is unusual for the diet of a community to be deficient in one nutrient only.

The fact that most clinical signs are non-specific does not preclude their use as indices of malnutrition. The frequent occurrence of one particular sign may give a lead to further investigations, while its association with other related signs at once raises its nutritional significance, both in the individual patient and in the community.

The interpretation of clinical signs can then be best made by using a "grouping of signs" which have been commonly found to form a pattern associated with the deficiency of a particular nutrient. Thus, while angular stomatitis can have various etiologies, if it is associated, in the individual or in a community, with one or more of the other signs in the "riboflavin deficiency" group, the likelihood of ariboflavinosis being present increases. The more numerous the signs present in one of the "groupings", the more probable the diagnosis of deficiency of the particular nutrient.

However, the clinical patterns on which these "groupings of signs" are based differ, in detail or in the most prevalent combinations of signs, in various parts of the world, depending upon the quality, degree, duration and speed of onset of the malnutrition. Other factors may include the balance of other foods in the prevailing diet, genetic influences, the age and activity of the person, and the environment in which he lives, as regards both environmental hygiene and climate, and exposure to infection and parasitism (Leitch, 1963).

Age plays a particularly important part in the clinical signs produced by nutrient deficiency. The different pictures produced in young children and in adults as a result of ascorbic acid lack or protein-calorie malnutrition are clear-cut instances. Furthermore, age plays a significant, though not fully understood, part in determining the incidence and nature of the eye manifestations of vitamin-A deficiency. In particular, the signs in early childhood appear to differ from those seen in schoolchildren (McLaren, 1963).

Patterns of clinical signs associated with specific nutrient deficiency cannot be standardized precisely for all areas of the world, although there is always a substantial agreement on the major features encountered. For example, the clinical picture of kwashiorkor, while varying in detail from one region to another, retains a core of signs found universally.

In some instances, a clinical appraisal of certain signs may be all that is required for a rapid screening survey, as in the use of the "niacin
deficiency" group of signs to ascertain the prevalence of overt pellagra. More often, however, survey work based on clinical signs, even with the groupings suggested, is best supported and confirmed by (a) appropriate anthropometric measurements, (b) selected biochemical tests, and (c) investigation of the local diet, preferably by food-consumption surveys, considered in relation to local ecological circumstances. Each of these methods is imperfect and incomplete; used together, in carefully planned and locally relevant combinations, they can give the fullest information.

**Guide to the Interpretation of Groupings of Clinical Signs**

1. **Protein-calorie malnutrition**

   **Protein-calorie malnutrition in adults and schoolchildren**

   The usual signs of protein-calorie malnutrition in adults and schoolchildren are:
   
   diminished subcutaneous fat, and
   
   muscle wasting.

   Other associated signs may include parotid enlargement, especially in schoolchildren (Gounelle, 1952; Raoult et al., 1957), oedema of the ankles, and gynecomastia in males (Venkatachalam, 1962b).

   **Anthropometric measurements.** There will be a low body weight for height, and measurements of subcutaneous fat and muscle will be considerably below the standard of reference.

   **Biochemical tests.** Hypo-albuminaemia may be present in advanced cases.

   **Protein-calorie malnutrition in young children**

   The signs suggestive of protein-calorie malnutrition in young children are:

   oedema,
   
   dyspigmentation of the hair,
   
   easy pluckability of the hair,
   
   thin sparse hair,
   
   straight hair,
   
   muscle wasting,
   
   diffuse depigmentation of the skin,
   
   psychomotor change,
   
   moon-face,
   
   hepatomegaly, and
   
   flaky-paint dermatosis.

   The clinical picture varies greatly in protein-calorie malnutrition in the early years of life, not only between the two major severe syndromes,
kwashiorkor and nutritional marasmus, but with regard to the lesser and much commoner degrees of deficiency. Differentiation of the various syndromes of protein-calorie malnutrition in young children, and possible clinical, biochemical and anthropometric methods of assessment of mild and moderate degrees of involvement in the community are considered in a later section (see page 179).

*Anthropometric measurements.* Growth retardation, as shown by a low body weight for age and by muscle depletion are characteristic findings (see page 182).

*Biochemical tests.* Hypo-albuminaemia is present in advanced cases, and a low urinary creatinine excretion may be found. Poor dietary protein intake is reflected by a low excretion of urea per gram of creatinine. The serum amino-acid imbalance test and the hydroxyproline excretion test (page 86) may show abnormality (Whitehead, 1965).

*Caloric overnutrition in children and adults (obesity)*

The signs of caloric overnutrition are:
- increased subcutaneous fat, and
- increased abdominal girth.

*Anthropometric measurements.* High weight for height, excessive skinfolds and an abnormally high abdomen/cheast-circumference ratio (see page 217).

2. Vitamin-A deficiency

The signs suggestive of vitamin-A deficiency are:
- Bitot's spots,
- conjunctival xerosis,
- corneal xerosis,
- keratomalacia,
- xerosis of skin, and
- follicular hyperkeratosis (type 1).

The clinical signs of avitaminosis A vary with age (McLaren, 1963). In particular, keratomalacia is principally seen in infancy and the preschool-age group, often associated with protein-calorie malnutrition, while Bitot's spots and conjunctival xerosis are more common in schoolchildren.1

Recent studies have suggested that both xerosis of the skin and follicular hyperkeratosis (type 1) are more usually due not to lack of vitamin A but to other environmental and dietary factors, including a low fat diet deficient in essential unsaturated fatty acids such as linoleic acid (Hansen et al., 1962).

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1 Ocular xerosis may also result from scar damage to lachrymal ducts, conjunctival overexposure due to distortion of the eyelids, or dehydration (Shevales, 1962).
Biochemical tests. Serum levels of carotene and vitamin A have been used.

Biophysical test. Classically, the dark-adaptation test has been employed for the detection of night blindness (hemeralopia), but is difficult to use in survey work, especially in young children.

3. Riboflavin deficiency

The signs suggestive of riboflavin deficiency are:
- angular stomatitis (or angular scars),
- cheilosis,
- magenta tongue,
- atrophic lingual papillae,
- dyssebacea,
- angular papebritis (angular blepharitis),
- scrotal (or vulval) dermatosis, and
- corneal vascularization.

Recent work has indicated the non-specificity of corneal vascularization and has also suggested that it is more commonly due to causes other than arboflavinosis (McLaren, 1963).


4. Thiamine deficiency

The common suggestive signs are:
- oedema,
- loss of ankle jerks,
- loss of knee jerks,
- motor weakness (squatting test),
- calf-muscle tenderness,
- sensory loss,
- cardiac enlargement, and
tachycardia.

Apart from oedema and signs of cardiovascular dysfunction—cardiac enlargement and tachycardia—the clinical signs associated with thiamine deficiency are all related to the central nervous system. The necessary tests are simple in theory, but extremely difficult to carry out satisfactorily in practice, especially among less sophisticated and often apprehensive rural populations during prevalence surveys. In these circumstances, subjective symptoms, such as paraesthesia, are even more unreliable. When communi-

\footnote{When appropriate, biochemical tests are given in the two categories suggested by the WHO Expert Committee on Medical Assessment of Nutritional Status (1965) (Table 7).}
cation is difficult, for linguistic and cultural reasons, and time is limited, histories of such complaints are rarely worth collecting.

Thiamine deficiency in babies (infantile beriberi) has a completely different clinical picture. Usually it is one of convulsions and acute cardiac failure in the early months of life. Assessment of the incidence of this condition is difficult owing to the acuteness of the illness and because of the other diseases that produce a similar clinical picture at this age. The age-specific mortality rate between two and five months is a useful guide, while indirect evidence may be gained by estimating the thiamine content of breast milk (Simpson & Chow, 1956).


5. Niacin deficiency

The signs suggestive of niacin deficiency are:
- pellagrous dermatosis,
- scarlet and raw tongue,
- atrophic lingual papillae,
- tongue fissuring, and
- malar and supraorbital pigmentation.


6. Vitamin-C deficiency

The signs suggestive of vitamin-C deficiency are:
- spongy and bleeding gums,
- petechiae,
- ecchymoses,
- follicular hyperkeratosis (type 2),
- intramuscular or subperiosteal haematoma, and
- epiphyseal enlargement (painful).

The clinical picture varies greatly with age. Infantile scurvy is characterized more by lassitude, anaemia, haematoma formation, especially subperiosteally, and painful epiphyseal enlargement, particularly at the costochondral junctions. Spongy, bleeding gums do not occur in the absence of teeth.

When teeth are present, the commonest cause of bleeding gums, in the absence of hypertrophy, is a varying degree of marginal gingivitis or pyorrhoea.

Biochemical tests. Category 1: Serum ascorbic acid. Category 2: White-blood-cell ascorbic acid, urinary ascorbic acid, load test.
7. Vitamin-D deficiency

Active rickets (in young children) is typically suggested by:
- epiphyseal enlargement (painless) (over 6 months of age),
- beading of ribs,
- persistently open anterior fontanelle (after 18 months of age),
- craniotabes (under 1 year of age), and
- muscular hypotonia.

Healed rickets (in older children or adults) is suggested by:
- frontal or parietal bossing,
- knock-knees or bow-legs, and
- deformities of the thorax (Harrison’s sulcus, pigeon chest).

Osteomalacia (in adults) may give rise to local or generalized skeletal deformities, especially of the pelvis, with tender bones.

The lack of specificity of these signs, including bow-legs, Harrison’s sulcus and craniotabes, has suggested that a minimum of three signs are needed for diagnosis, preferably backed by biochemical and radiographic evidence.

Biochemical tests. Serum alkaline phosphatase level.

Radiographic examination. Changes in the ends of long bones, especially at the wrist.

8. Iron deficiency

Iron deficiency is suggested by:
- pale conjunctiva,
- koilonychia (in older children and adults), and
- atrophic lingual papillae.


Additional investigations. These may be necessary to exclude other nutritional causes of anaemia (e.g., folic acid or vitamin-B₁₂ deficiency), and to assess possible contributory causes of the anaemia. They may include a stool examination for hookworm ova and occult blood, a thick blood film for malarial parasites and, in populations of African descent, a sickling preparation and electrophoresis for abnormal haemoglobins.

9. Folic acid or vitamin-B₁₂ deficiency

This condition is usually accompanied by pale conjunctiva due to anaemia.

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1 Hyperpigmented extremities have been described in vitamin-B₁₂ deficiency in Indian infants (Jadhav et al., 1962).
Biochemical and haematological tests. Category 1: haemoglobin, thin blood film. Category 2: serum concentrations of folic acid and vitamin B₁₂.

10. Iodine deficiency

A deficiency of iodine produces enlargement of the thyroid.¹

Biochemical tests. No simple tests are available, nor are they required for standard goitre surveys. For research purposes and if elaborate equipment is available, the urinary iodine can be assessed and various tests for thyroid function undertaken.

11. Excess of fluorine (fluorosis)

An excess of fluorine is suggested by mottled dental enamel.

This sign, however, has to be distinguished in its early stages from enamel hypoplasia and from various congenital conditions (Russell, 1961). According to Grech & Latham (1964), mottling of the finger nails may also be found.

Radiographic examination. Although rarely of practical importance in a prevalence survey, in chronic advanced cases radiographic examination of the spine will show increased density of the bones, with calcification of ligaments.

Chemical test. If possible, analysis of representative water samples should be made. More than 2 ppm of fluoride is a positive result.

Therapeutic Trials

Therapeutic trials can be a useful extension of clinical assessment where the need is to establish the identity of a deficiency syndrome or to differentiate between two conditions with similar clinical manifestations. They can, for example, be of value in defining the nutritional etiology of anaemia, when effectiveness will be assessed by haematological response, as judged by a rise in the reticulocyte count and haemoglobin level (Stott, 1960).

This type of investigation will generally be carried out at the end of a survey or as part of a follow-up on a limited number of affected persons. The trial will also be guided by biochemical and dietary findings.

Therapeutically effective doses of the single nutrient being investigated are given to the selected persons for what is judged to be a sufficient time to produce results. If the nutrient is not given parenterally, biochemical tests to ensure that absorption has occurred are desirable.

At the same time, a control group of people with the same clinical features should be given a placebo in order to eliminate changes that could

¹ Size assessed by the technique of Perez, Scrimshaw & Munoz (1960).
occur spontaneously, such as those due to seasonal factors. The trial should be a "double-blind" test in that the clinical observer should not be able to differentiate between nutrient and placebo until after the trial is completed.

Clinical change must be critically evaluated, preferably quantitatively, as by measurement of the size of a lesion, or by before-and-after photographs, preferably in colour.

**Rapid Clinical Surveys**

These are designed to detect the most characteristic signs of one or several nutritional deficiencies. They are of most value when the plane of community nutrition is low. They can be carried out by medical staff or by paramedical personnel who have been specially selected and trained and are working under the supervision of a competent nutritionist. The data collected should be recorded on a special record form, which lists the signs that are considered to be both particularly characteristic and easily identifiable during a field survey.

Experience has shown that if these rapid surveys are to be of real value, they must be carried out on samples that are sufficiently large, when judged by standard statistical considerations.

A simple schedule will be employed, which may include some or all of the following signs:

- **Hair:**
  - dyspigmentation
  - easy pluckability
  - sparseness

- **Face:**
  - moon-face

- **Eyes:**
  - Bitot's spots
  - conjunctival xerosis
  - pale conjunctiva

- **Mouth:**
  - angular stomatitis
  - cheilosis
  - glossitis
  - swollen, bleeding gums

- **Thyroid gland:**
  - goitre

- **Skin:**
  - oedema (bilateral)
  - follicular hyperkeratosis (type 1)
  - pellagrous dermatosis

- **Skeleton:**
  - epiphyseal enlargement (wrist)
  - rickety rosary
  - persistently open anterior fontanelle
  - Harrison's sulcus
  - bowing of skull
  - knock-knees
  - bow-legs

Rapid surveys of this type are usually mainly clinical, but may include limited anthropometry, especially weight measurements. They have limited objectives and are often concerned with a specific problem, such as goitre or protein-calorie malnutrition. They are inexpensive, speedy and require only limited staff. However, they are at best screening procedures that indicate whether more detailed surveys are desirable.
Occasionally, rapid screening surveys may be based solely on a laboratory test, such as the haemoglobin estimation for anaemia or the urinary thiamine test for deficiency of this vitamin.

**NUTRITIONAL ANTHROPOMETRY**

Nutritional anthropology is concerned with the measurement of the variations of the physical dimensions and the gross composition of the human body at different age levels and degrees of nutrition.

In its modern scientific form, it is a comparatively recent development requiring well-organized research centres, elaborate equipment and highly sophisticated mathematical knowledge. Its newer techniques have been used to a limited extent in the developing regions of the world, especially in young children. The interpretation of findings anywhere is always complex and often controversial, even to leading authorities. The normal healthy well-fed human body can vary so much that interpretation of the nutritional significance of variations in physical dimensions is peculiarly difficult.

The present account, together with subsequent sections dealing with the interpretation of results and with special problems in different age-groups, is not concerned with the nutritional assessment of the individual, but rather suggests simple methods that will supply useful, if approximate, information concerning the nutritional profile of the community and be of value in guiding public health programmes.

The methods suggested here can be carried out with a small staff and little equipment. At the same time, they must be regarded as to some extent of an interim nature, in so far as they require much additional large-scale evaluation in the field and may be superseded by newer procedures.

Growth is influenced by biological determinants, including sex, intrauterine environment, birth order, birth-weight in single and multiple pregnancies, parental size and genetic constitution, and by environmental factors, including climate, season and socio-economic level. In the final analysis the environment seems to produce its effect mostly by the presence (or absence) of infective, parasitic and psychological illnesses (Patton, Gardner & Richmond, 1963) and, above all, by the plane of nutrition.

In general, recent work tends to suggest that environmental influences, especially nutrition, are of greater importance than genetic background or other biological factors. Certainly the physical dimensions of the body are much influenced by nutrition, particularly in the rapidly growing period of early childhood. Selected body measurements can therefore give valuable information concerning certain types of malnutrition in which body size and gross body composition are affected.

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1 A valuable guide to nutritional anthropology has recently been prepared in Spanish by Ramos-Galvan (1965).
Dramatic historical examples of the effect of nutrition on anthropometric measurements are demonstrated in the lower weights and heights of European schoolchildren in Paris (Gounelle, Vallette & Moine, 1942; Laporte, 1946) following prolonged and severe war-time dietary restrictions. Conversely, and probably mainly because of improving nutrition, the stature and weight of children and adults have increased progressively over the past hundred years in both North America (Meredith, 1941) and Europe (Clements, 1953), and more recently in Japan (Mitchell, 1962) and Jamaica (Ashcroft & Lovell, 1965).

Growth and physique can also be affected by bacterial, viral and parasitic infections. These factors require differentiation, but, under practical circumstances in many developing tropical regions, they may together form part of a person's total disease burden, and have secondary nutritional consequences. It is difficult, if not impossible, to disentangle these secondary effects underlying primarily dietary malnutrition. This is especially so in kwashiorkor—one of the two principal forms of severe protein-calorie malnutrition of early childhood. This condition is almost never exclusively dietary in origin, but rather the result of other cumulative stresses as well, including the nutritional ill-effects of intestinal helminths, bacterial and viral infections (such as tuberculosis, whooping cough and measles), persistent malaria, and psychological trauma associated with weaning (Patton, Gardner & Richmond, 1963).

The methods and the measurements employed in anthropometry can vary greatly in number and complexity. Obviously those chosen will depend on the purpose and objectives of the particular survey or study. Detailed, elaborate and time-consuming techniques and analyses, such as refined scientific procedures for estimating body composition, can usually be carried out only by the laboratory research worker.

For the practical nutritionist in the field, the problem is:

(a) to select the minimum number of relatively simple methods that can give useful, if approximate, practical information on a community basis;

(b) to understand thoroughly the practical techniques involved; and

(c) to interpret the results and express them in a way that is understandable to workers anywhere in the world.

Much of the world literature on nutritional anthropometry is concerned with adults, especially in well-fed communities where obesity is a health problem, so that the estimation of body fat in relation to weight and height figures prominently. Similarly, investigations of children have also been concerned mainly with the evolution of "standards", and with problems of growth and development among children in North America and Europe.

For the field worker in a developing tropical country, nutritional anthropometry appears to be of greatest value in the assessment of growth failure
and undernutrition, principally from lack of protein and calories. In particular, the often numerous less advanced states of protein-calorie malnutrition in early childhood can probably be best detected objectively by deviations from the usual rapid growth pattern characteristic of this age-group, as shown especially by a low body weight and by depletion of protein stores, as indicated by a subnormal muscle mass.

**Standardization of Techniques**

*Methods*

The apparent simplicity of making measurements is deceptive (Brozek, 1956), and yet in a survey such measurements as weighing may be delegated to the most junior, least well trained member of the team, who is commonly left to work without adequate supervision and without regular checking of his apparatus. The effects are particularly unfortunate, since the inaccurate results obtained are expressed numerically and too often viewed as scientifically precise and objective data.

The time spent in obtaining a measurement is only a small fraction of the time required for subsequent calculations and interpretation, and effort as well as time are wasted if the original measurement is inaccurate.

The techniques employed, including such apparently simple and commonplace procedures as weighing, must be carefully carried out, standardized, thoroughly understood by all team members, and given adequate preliminary practical testing to ensure uniformity of results. Details of standardized techniques for the most useful procedures are set out in a subsequent section. Particular accuracy of both technique and equipment is needed with small children, especially when growth is being assessed by the measurement of small increments.

If many people are to be examined, sufficient personnel should be available to permit of rest periods. Otherwise the repetition, monotony and physical strain of making large numbers of precise measurements, especially on uncooperative young children, lead to fatigue, boredom and inevitable error. Lastly, the average time required to carry out procedures must be known, in order to determine how many subjects can be dealt with at each session.

*Instruments*

The selection of suitable instruments is extremely important. They must be sufficiently accurate for the particular study, simple to use, inexpensive and "readily portable and rugged enough to withstand severe handling" (Pett & Ogilvie, 1956). They require careful pre-testing and frequent checking and calibration. Details of appropriate instruments for various practical procedures are given later.
Direct Assessment of Human Groups

Description of methods

In all published results, the fullest details of methods used must be clearly stated. For example, the precise technique used for weighing (e.g., the scales used, whether clothes worn or nude) must be set down.

If possible the investigator should dictate each measurement to a recorder, who repeats aloud the figure as it is given to him. This method speeds up the procedure and reduces clerical error.

Standards of Reference

Community standards for anthropometric measurements are difficult to define. What is usually meant are values that can be employed as a "frame of reference".

Standards for a community are usually obtained by measuring a statistically adequate sample of a healthy, well-fed segment of the population whose ages are known with certainty. For all age-groups, measurements made cross-sectionally will suffice.

For children, however, values should, if possible, also be obtained by more time-consuming longitudinal methods—that is by serial measurements of a sample of children over some years—in order to determine the pattern of growth for the particular population in relation to known episodes in the children’s lives.

As a compromise between these two methods, the accelerated longitudinal method of Bell (1964) or the mixed longitudinal method (Harrison et al., 1964) may be employed.

From this type of data, the range of distribution of values for these normals can be determined and the results expressed as the average or mean value plus or minus twice the standard deviation (mean ± 2 S.D.) (Falkner, 1962a). The most useful and practical ways of expressing results below these standards are considered in a later section.

However, it must again be stressed that the most desirable, or optimal, anthropometric values or standards are not known with certainty for any community. There has been a constant secular trend in the past century towards heavier and taller populations in the western world (Meredith, 1941) that has made previous "standards" progressively out-of-date.8

1 The desired end-product of optimal nutrition at present lacks definition, and Barness & Guigne (1962) stress the uncertainty of whether the goal is "to produce muscle-men, geniuses, giants, dwarfs or Methuselahs".
2 Twice the standard deviation (± 2 S.D.) covers 95% of the distribution and permits percentiles to be calculated later, if required.
3 According to Norwegian records, this secular trend commenced in the 1830s, and in Western Europe as a whole there has been a consistent increase in adult height by about 1 cm per decade over the past century (Harrison et al., 1964). The possibility that this trend has ceased in the USA is suggested by recent measurements of private-school children (Bakwin & McLaughlin, 1964).
4 This secular trend of this type can be downwards and is suggested by the smaller sizes of preserved skeletons in medieval Iceland, when adverse climatic conditions developed (Harrison et al., 1964), and by the inferior stature of the modern Peruvian peasants compared with their pre-Conquestador ancestors, which Graham (1966) suggests may be due to dietary change and, in particular, the abandonment of high-protein quinoa (Chenopodium quinoa) as the main staple.
That this runs parallel with an improvement in nutrition and other environmental influences, such as disease control, seems certain. At the same time, there may well be developing an undesirable relation between larger, early-maturing, possibly overfed populations and a subsequent disease pattern in adulthood that includes, among other things, an increasing incidence of atherosclerosis and obesity.

Optimum growth levels can be evaluated logically only in relation to present and future health. Evaluation of this kind is difficult to do in a long-lived species such as man, but it is the basis for the “desirable” standards of weight for adults laid down by the Society of Actuaries (1959), which are related to cardiovascular disease and longevity.

Local standards of reference. It should be the ultimate aim of nutritionists to prepare and use local standards for different ethnic groups with potentially different patterns of growth. To cite an extreme instance, height standards for the pygmies of Rwanda are obviously inappropriate for their extremely tall nilo-hamitic neighbours, the Tutsi.

Body proportions appear to vary in different groups of peoples. This is partly genetic, possibly being related in some instances to climatic adaptation, as exemplified by the contrasting shape and size of the Arctic-dwelling Eskimo and the tall, slender Dinka of equatorial Africa.

However, physique is also related to nutrition, as has been demonstrated by the increase in height as well as weight of second- and third-generation Japanese Americans in California compared with their ancestral stock in Japan (Greulich, 1957).

Difficulties in preparing local standards are great. Large numbers of careful measurements have to be made among the healthy, well-fed section of the community whose ages are known. This is a major undertaking, but, when staff and other priorities permit, a carefully planned accumulation of these important base-line data should be carried out, using standardized techniques, fully detailed in the recording of the results.

It is particularly desirable to collect reliable present-day local standards for young children, but this is often especially difficult (Dean, 1965). In some cases, only a small proportion of children may be well fed, healthy and with their ages known exactly, owing to inadequate birth registration. If practicable, measurements should be made of singleton children of the educated, prosperous elite section of the community, if such exist in sufficient numbers, excluding those with serious illness or congenital abnormalities. In all instances, the group measured should be ethnically homogeneous, fully described and statistically adequate numerically.

Many so-called “standards” that have been compiled for pre-school children in developing tropical countries are based on measurements of children from lower socio-economic groups, who are, in fact, usually undernourished from six months of age onwards and continuously exposed to a
succession of infective and parasitic diseases (Dean & Jelliffe, 1960). Optimum data from the offspring of the truly well-fed, medically and socially protected elite are much needed and should be the aim when local standards are being constructed.

Ideally, both cross-sectional and longitudinal serial measurements are needed for children, but the latter take years of patient supervision and careful collection of data, to ensure the accurate recordings of small increments. Longitudinal measurements offer the advantages of permitting accurate knowledge of age, ensuring genetic homogeneity and enabling growth to be correlated with each child’s history and background, including diet, minor illnesses and socio-economic circumstances. They give information on possible variations in patterns of growth and developmental phases, such as adolescence, but may be already out-of-date by the time they are ready for use. More often only cross-sectional measurements are practicable. They are more quickly obtained and give information on current conditions.

For convenience, measurements have often been made in easily accessible groups, such as schoolchildren and adults, especially in the police or armed forces. However, because of the age distribution of protein-calorie malnutrition, it is most important to have standards of growth for the first five years of life.

To prepare local growth standards by cross-sectional methods to cover the vulnerable first five years of life, it is necessary to measure at least 30 children of each three-month period and to calculate the means (averages) plus or minus twice the standard deviation (± 2 S.D.). Results may sometimes be more vividly portrayed as a graph. Separate results can be collected for each sex, but, for practical nutritional anthropometry in the community, standards for boys and girls may be considered together in these early years. Apart from the measurement of subcutaneous-fat thickness, there is not much difference in the commonly employed measurements.

In later childhood and for adults, separate standards are required for the sexes, and must be based on the examination of statistically adequate groups.

The need for different standards of weight and height (and other linear measurements) for different age-groups is obvious. In addition, however, consideration has to be given to relative rates of growth and of maturation of different tissues at various ages, and to the possible effects of malnutrition at different periods of life.

Normal growth is an uninterrupted process, although the rate is uneven, with recognized periods of rapid increase, particularly the first six months of life and the puberty “spurt”. In protein-calorie malnutrition, however, it is slowed or even halted. Suggested average expected weight gains at different periods of childhood are given in a later section (Table 19, page 196).
Differences of body proportion at various stages of human development are also well recognized—for example, the relatively large head of the newborn compared with that of the adult. Of particular interest in nutritional anthropometry is the variation of subcutaneous fat and muscle at different ages. The thicker layer and different distribution of fat in healthy babies make different standards necessary for this age and for the normally leaner pre-school-age child.

A local anthropometric standard will often have a usefulness extending beyond the actual group for whom it was originally prepared. It may be appropriate to use the same standards for groups of similar genetic stock, although it will always be difficult to know how far afield the same values may be employed with exactness. For example, growth standards compiled for Baganda children could be used among the Basoga, another genetically similar Bantu community in Uganda. In some parts of the world, as in the West Indies, where people of different ethnic groups often intermarry, it may be difficult to decide on precise local standards that cover all genetic possibilities.

General standards of reference

As noted, carefully compiled local standards, based on statistically adequate samples, are difficult to prepare. Many workers have noted that really well-fed people of various ethnic groups tend to approximate to standards, especially weight levels, similar to those found in well-nourished Caucasians in Europe and the USA. This secular trend has already been noted for Japanese Americans (Greulich, 1957), and for Japanese children of the upper socio-economic group in the homeland in the last decade (Mitchell, 1962).

Furthermore, Ford (1964) has collected evidence that well-nourished infants and pre-school children of various genetic backgrounds attain weight levels so near to those obtained in the Harvard Longitudinal Studies (Stuart & Stevenson, 1959) that these values may be used for assessing malnutrition. Similar findings have been reported for Central American pre-school children (Hurtado, J. J.—personal communication, 1962), and for West Indian schoolchildren in Haiti (King et al., 1963) and Jamaica (Ashcroft & Lovell, 1964; Ashcroft et al., 1965).

It follows that the use of such general standards of reference appears to be of value as a public health approximation (Woodruff, 1966), with the proviso that, wherever feasible, control measurements should also be made locally from children of the well-fed elite. Obviously, the genetic extremes among the sub-groups of mankind, such as the pygmies, cannot be included.

Other indirect evidence supporting the feasibility of using general standards of reference includes the increased birth-weight in well-nourished

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1 This may take two well-nourished generations, as a small malnourished mother will give birth to a low-birth-weight neonate.

2 These measurements are referred to as "the Harvard Standards" throughout this monograph.
sections of tropical communities, and the excellent weight gain of most babies in developing regions while on the abundant, protein-rich diet furnished by on-demand breast feeding in the early months of life. Conversely, following the years of war-time nutritional deprivation, the weights and heights of some groups of European children fell to levels comparable to those "normally" found in some developing countries (Laporte, 1946).

In any case, it is often necessary, because of a lack of local measurements, to use a (possibly) genetically less appropriate but widely available general standard. Several of these are available, but it is suggested that the Harvard Standards should be used for weight and height measurements in young children. These data, although derived from the growth of Caucasian children in Boston from 1930 to 1956, offer the advantages of having been carefully compiled longitudinally on a large series, of being widely available in Nelson's *Textbook of Pediatrics*, and of being used already by paediatricians in many countries. For schoolchildren where weight-for-height-for-age data are required, the Baldwin-Wood Standards should be used (Baldwin & Wood, 1923; Baldwin, 1925). The Harvard data have not been analysed in this way, but can be used for weight-for-height standards where the age is not known.

Sources of general standards of reference for other measurements (e.g., triceps skin-fold, arm circumference etc.) are given in Annex 1.

For adults, the weight-for-height tables suggested are derived by ICNND (1963) from the figures compiled by the Society of Actuaries (1959)\(^1\) and considered to be "desirable".

Sources of other general standards suggested for older children and adults are given in Annex 1.

Despite the practical usefulness of the general standards of reference given, their arbitrariness must also be noted, because the figures for different age-groups and measurements have been collected by various investigators using varying techniques in non-identical populations in different, recent decades.

**Conclusion**

Local anthropometric standards should be prepared and used wherever possible, because they may often be considered a more realistic goal. They are, however, very difficult to collect.

In addition, general standards of reference should be employed, for, although they may be genetically unsuitable, they supply a yardstick with which results from surveys at different times and places can be compared. While they may be locally relevant as a goal, they are more usually of value as a standard of reference.

Where available, results should be expressed in terms of both standards. In all cases, precise details of the standards employed must be known.

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1 These measurements are referred to as the "Actuaries Standards" throughout this monograph.
(e.g., techniques, groups, age assessment, etc.) and must be clearly stated in the published results.

**Age Assessment**

Many persons living in the developing regions of the tropics are ignorant of their exact age, or occasionally may employ a system of age classification different from the western method. This is understandable since precise age has little significance unless it has a recognized social value, e.g., in relation to legal responsibility, admission to school, pension rights, etc. Among some peoples, functional or physiological age-groups are recognized—e.g., "big enough to be able to herd goats", or "capable of carrying a younger sibling", or "marriageable".

Often transitions from one group to another are recognized by special ceremonies and by the wearing of different clothes, decorations or hair style thereafter. These include initiation rites in some communities, e.g., the elaborate ceremony and short hair-cut carried out before a girl can enter the marriageable group among the San Blas Indians of Panama (Jelliffe et al., 1961).

For adults, all that may be possible is to consider the two sexes in broad age-groups—young adults, adults, old adults. However, differentiation may sometimes be difficult in groups where the scalp hair is shaved, where there is no "middle-aged" obesity, and where facial wrinkles are less prominent against a darker complexion, or, conversely, where women age rapidly with continuous child bearing and too much work. A long-term local calendar of important events may have to be constructed.

More-exact age-assessment is desirable in the anthropometry of young children, when protein-calorie malnutrition has its main incidence. When dealing with infants and pre-school children, ages should, if possible, be known to the month. For schoolchildren, assessment of ages to the nearest three months should be attempted.

In field-survey circumstances, age assessment in young children may be attempted in various ways. Documentary evidence may, though rarely, be forthcoming, including birth certificates, horoscopes and baptismal certificates. Careful prior enquiries must always be made and, wherever possible, the parents must be encouraged to bring these vital papers.

Sometimes, the mother may not know the child's age, but may be able to recite the month of birth, and occasionally the day as well. If this is so, the mother will often recall details of the youngest child only, not those of the older siblings. If dates are known, they should be recorded as given and the ages calculated later.

In some communities, the period of the year in which the child was born can be recognized by the name given, e.g., "born during millet harvest-
ing ", or as belonging to a certain ritual age-set; or there may be a local lunar calendar, as among the San Blas Indians of Panama, e.g., iguana egg-laying moon, corn-sprouting moon, etc. (Jelliffe et al., 1961b). It may be possible to obtain information in relation to Muslim lunar months.

Often the only practicable method may be to construct a locally relevant calendar (Tukei, 1963) based on events in the preceding years, including agricultural, climatic and political occurrences, as well as natural or man-made disasters (Table 3). However, such a calendar takes weeks to prepare and pre-test in the field, while its use in survey circumstances is laborious, time-consuming, and least satisfactory with the unsophisticated communities for which it is intended. Calendars will plainly have to be specific for different communities.

As approximate supporting evidence, the young child’s deciduous dental eruption should be noted on the survey form, the standard visual coding shown in Fig. 32 being used. It has been shown that the time-range of eruption in inadequately nourished children of lower socio-economic groups in Peru (Graham & Morales, 1963), in various parts of Africa (Welbourn, 1956; Sénécal, Masse & Moreigne, 1959), and in the New Guinea Highlands (Voors & Metselaar, 1958; Bailey, 1963a) is similar to that found among children in Europe and North America, although Puyet, Downs & Budeir (1963) found some delay in Arab children.

**FIG. 32. STANDARD VISUAL CODING OF DECIDUOUS DENTITION**

<table>
<thead>
<tr>
<th>(Right upper jaw)</th>
<th>E</th>
<th>D</th>
<th>C</th>
<th>B</th>
<th>A</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>(Left upper jaw)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Right lower jaw)</td>
<td>E</td>
<td>D</td>
<td>C</td>
<td>B</td>
<td>A</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>E</td>
<td>(Left lower jaw)</td>
</tr>
</tbody>
</table>

Code: A = central incisor; B = lateral incisor; C = cuspid; D = first molar; E = second molar.

Example shows both lower central incisors erupted.

However, times of dental eruption can vary greatly in normal children, and further work is needed to establish local standards, because some presumed genetic differences in tooth-eruption timing have been noted in different parts of the world (Garn, Lewis & Kerensky, 1964). Strangely little precise information appears to be available on the effect of kwashiorkor on the appearance time of deciduous teeth, although the clinical impression is that it is little affected, if at all. Trowell, Davis & Dean (1954) remark on “the incongruous sight of the tiny child with his mouth crowded with teeth”.

Evidence concerning the time of dental eruption in children suffering from nutritional marasmus is incomplete. In experimentally severely undernourished piglets, dental eruption is not delayed (McCance, 1964), although
### Table 3. Calendar for the Assessment of the Age of Young Baganda Children *

<table>
<thead>
<tr>
<th>Main events of the year</th>
<th>Rainy seasons</th>
<th>Month</th>
<th>Recalled seasonal or special events</th>
<th>Age on 31.12.1982</th>
</tr>
</thead>
<tbody>
<tr>
<td>1959</td>
<td>Togo</td>
<td>January</td>
<td>Beginning of New Year</td>
<td>years months</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Picking and selling of cotton crop</td>
<td>4 4</td>
</tr>
<tr>
<td></td>
<td>Rain</td>
<td>February</td>
<td>Children go back to school</td>
<td>3 11</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>End of cotton picking; selling continues</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dumbi</td>
<td>March</td>
<td>Muslim Fast, ending with Id celebration (Akusilaba bya abasiramu)</td>
<td>3 10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>April</td>
<td>Easter (Pasaka) celebrated</td>
<td>3 9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>White ants fly</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>May</td>
<td>Early cotton planting</td>
<td>3 8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>June</td>
<td>Main cotton planting</td>
<td>3 7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Weeding early cotton</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>July</td>
<td>Main cotton weeding</td>
<td>3 6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>August</td>
<td>Main groundnut harvest</td>
<td>3 5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>September</td>
<td>Coffee picking</td>
<td>3 4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>October</td>
<td></td>
<td>3 3</td>
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<tr>
<td></td>
<td></td>
<td>November</td>
<td>Kabaka’s birthday</td>
<td>3 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>December</td>
<td>Christmas (Noël)</td>
<td>3 1</td>
</tr>
<tr>
<td>1960</td>
<td>Togo</td>
<td>January</td>
<td>Beginning of New Year</td>
<td>3 3</td>
</tr>
<tr>
<td></td>
<td>Rain</td>
<td>February</td>
<td>Picking and selling of cotton crop</td>
<td>2 11</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Children go back to school</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dumbi</td>
<td>March</td>
<td>Muslim Fast, ending with Id celebration (Akusilaba bya abasiramu)</td>
<td>2 10</td>
</tr>
<tr>
<td></td>
<td>Rain</td>
<td>April</td>
<td>Easter (Pasaka) celebrated</td>
<td>2 9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>White ants fly</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>May</td>
<td>Early cotton planting</td>
<td>2 8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>June</td>
<td>Main cotton planting</td>
<td>2 7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Weeding early cotton</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>July</td>
<td>Main cotton weeding</td>
<td>2 6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>August</td>
<td>Main groundnut harvest</td>
<td>2 5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>September</td>
<td>Coffee picking</td>
<td>2 4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>October</td>
<td></td>
<td>2 3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>November</td>
<td>Kabaka’s birthday</td>
<td>2 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>December</td>
<td>Christmas (Noël)</td>
<td>2 1</td>
</tr>
</tbody>
</table>

* Reproduced by permission from Tukei (1963).
TABLE 3. CALENDAR FOR THE ASSESSMENT OF THE AGE OF YOUNG BAGANDA CHILDREN  
(continued)

<table>
<thead>
<tr>
<th>Main events of the year</th>
<th>Rainy seasons</th>
<th>Month</th>
<th>Recalled seasonal or special events</th>
<th>Age on 31.12.1962</th>
</tr>
</thead>
<tbody>
<tr>
<td>1961</td>
<td>Togo Rains</td>
<td>February</td>
<td>Children go back to school</td>
<td>1 11</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>End of cotton picking; selling continues</td>
<td></td>
</tr>
<tr>
<td>Year when feasting for Kabaka's return from London Conference</td>
<td>Togo Rains</td>
<td>March</td>
<td>Muslim Fast, ending with Id celebration (okusilba bya abasiramu)</td>
<td>1 10</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Democratic Party win general elections, boycot ted by Buganda</td>
<td></td>
</tr>
<tr>
<td>Year which ended with bad floods closing many roads</td>
<td>Dungi Rains</td>
<td>April</td>
<td>Easter (paska) celebrated</td>
<td>1 9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>White ants fly</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>May</td>
<td>Early cotton planting</td>
<td>1 8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>June</td>
<td>Main cotton planting</td>
<td>1 7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Weeding early cotton</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>July</td>
<td>Main cotton weeding</td>
<td>1 6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>August</td>
<td>Main groundnut harvest</td>
<td>1 5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>September</td>
<td>Coffee picking</td>
<td>1 4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Very heavy rains and flooding of roads</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>October</td>
<td>Kabaka went to first London Conference</td>
<td>1 3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>November</td>
<td>Kabaka's birthday</td>
<td>1 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>General feasting for Kabaka's return from Conference</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>December</td>
<td>Tanganyika became independent</td>
<td>1 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Christmas (Moef)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>End of year</td>
<td></td>
</tr>
<tr>
<td>1962</td>
<td>Togo Rains</td>
<td>January</td>
<td>Beginning of New Year</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Picking and selling of cotton crop</td>
<td></td>
</tr>
<tr>
<td>The year Uganda became independent</td>
<td>Dungi Rains</td>
<td>February</td>
<td>Children go back to school</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>End of cotton picking; selling continues</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>March</td>
<td>Muslim Fast, ending with Id celebration (okusilba bya abasiramu)</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Kabaka-Yekka won the Lukiko elections</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>April</td>
<td>Uganda People's Congress-Kabaka-Yekka won National Assembly elections</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Easter (paska) celebrated</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>White ants fly</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>May</td>
<td>Mr Obote succeeded Mr Kiwanuka as Prime Minister</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Early cotton planting</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>June</td>
<td>Main cotton planting</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Weeding early cotton</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>July</td>
<td>Main cotton weeding</td>
<td>5-6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>August</td>
<td>Main groundnut harvest</td>
<td>5-8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>September</td>
<td>Coffee picking</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>October</td>
<td>Uganda became independent</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>November</td>
<td>Kabaka's birthday</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>December</td>
<td>Christmas (Moef)</td>
<td>1-0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>End of year</td>
<td></td>
</tr>
</tbody>
</table>
McLaren, Ammoun & Houri (1964) have shown that deciduous teeth erupt later in marasmic infants.

A method of assessing approximately the age-range from dental eruption is suggested in Table 4 as judged by average eruption times. Bailey (1963a) has suggested that, as an approximation, the simple addition of 6 to the number of teeth erupted—that is, with the crown of the tooth visible through the gum—gives the rough age in months, and this proposal has the advantage of requiring no memorizing or consulting of tables.

**TABLE 4. AVERAGE ERUPTION TIME OF DECIDUOUS TEETH**

<table>
<thead>
<tr>
<th>Tooth</th>
<th>Lower jaw</th>
<th>Upper jaw</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central incisor</td>
<td>6 months</td>
<td>7 1/2 months</td>
</tr>
<tr>
<td>Lateral incisor</td>
<td>7 months</td>
<td>9 months</td>
</tr>
<tr>
<td>Cuspids</td>
<td>16 months</td>
<td>18 months</td>
</tr>
<tr>
<td>First molar</td>
<td>12 months</td>
<td>14 months</td>
</tr>
<tr>
<td>Second molar</td>
<td>20 months</td>
<td>24 months</td>
</tr>
</tbody>
</table>


a Inclusors: range ± 2 months
b Molars: range ± 4 months

The stage of dental eruption can be combined with a careful measurement of head circumference as a method that may narrow the range. It is obvious that although, at best, these methods can act only as guides, they can certainly suggest the lower age limit. Other physiological yardsticks, such as bone age and sexual maturation, are also variable, and anyhow not relevant or practicable in cross-sectional prevalence-survey work.

The stage of neuromuscular development is usually of only slight value, as it is very variable in the healthy, and particularly difficult to test in anxious children in the field. The picture may also be obscured by the muscle wasting and weakness characteristic of protein-calorie malnutrition.

The presence of older or younger siblings, or a pregnant mother, may provide further useful information in guiding age-assessment of the individual child, although in some groups it is difficult for the observer in a prevalence survey to discover whether the children do in fact belong to the particular women. For example, among the Baganda, the sending of young children to stay with relatives is widely practised and, by local convention, the woman with whom they are staying will not like to say that a particular child is not her own. A knowledge of children's ages is one of the advantages of long-term longitudinal studies.
Age-assessment can sometimes be best attempted by a combination of dental eruption, head circumference, local calendar and presence of siblings. However, as age is still often difficult to evaluate, attention is given later to methods that can be used to assess growth-failure where the age is not known (Table 22, page 200).

For schoolchildren, attempts should be made to assess the age to within three months. Parents or teachers may supply information or documentary evidence. A local calendar covering an adequate time-range can be constructed for use with parents. The eruption of the permanent dentition can be noted (Table 5), but the significance must be interpreted cautiously, in view of individual variation and evidence that genetic factors may influence the time of eruption (Chagula, 1960).

<table>
<thead>
<tr>
<th>Tooth</th>
<th>Lower jaw (years)</th>
<th>Upper jaw (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central incisors</td>
<td>6-7</td>
<td>7-8</td>
</tr>
<tr>
<td>Lateral incisors</td>
<td>7-8</td>
<td>8-9</td>
</tr>
<tr>
<td>Cuspids</td>
<td>9-10</td>
<td>11-12</td>
</tr>
<tr>
<td>First bicuspids</td>
<td>10-12</td>
<td>10-11</td>
</tr>
<tr>
<td>Second bicuspids</td>
<td>11-12</td>
<td>10-12</td>
</tr>
<tr>
<td>First molar</td>
<td>6-7</td>
<td>6-7</td>
</tr>
<tr>
<td>Second molar</td>
<td>11-13</td>
<td>12-13</td>
</tr>
<tr>
<td>Third molar</td>
<td>17-21</td>
<td>17-21</td>
</tr>
</tbody>
</table>


Measurement Techniques

Of the almost unlimited number of possible body measurements, those selected should be the simplest and quickest to take and the easiest to reproduce that will give the maximum information concerning the particular nutritional problem under investigation. In the developing regions of the world, this will almost always be the problem of protein-calorie malnutrition, both in adults, schoolchildren and, especially, pre-school-age children—in direct contradistinction to many studies carried out in both America and Europe, where the treatment of the problem has often centred on obesity and excessive weight.

1 The techniques suggested are based on those described by the Committee on Nutritional Anthropometry (1956), Falkner (1960, 1962b), and Prinsloo (1964).
The most usual measurements are those made to assess (a) body mass, as judged by weight; (b) linear dimensions, especially height; and (c) body composition and reserves of calories and protein, as judged by the principal superficial soft tissues—subcutaneous fat and muscle.¹

Measurements should be made and recorded in the metric system. However, in areas where the only available weighing machines record in pounds and ounces, measurements may be taken in these units and later converted into metric units prior to comparison with standards of reference (Annex 1).

1. Weight

Weight is the anthropometric measurement most in use. Its potential value, especially for children, is appreciated not only by health personnel, but often by less educated parents, for whom it is useful as a source of health education.

In developing regions, the prevalence of protein-calorie malnutrition appears to be best indicated by weight deficiency in all age-groups and by growth failure in children. Weighing is the key anthropometric measurement.

Weight estimations can be made on isolated occasions, as in many surveys, or repeated at intervals under special conditions, as at child-welfare clinics, schools, prenatal clinics, or in longitudinal studies. These serial measurements give a better index of actual growth or growth failure, but attention should be paid to possible difficulties of identification that may arise if the particular population is mobile and if name-changing is a common practice culturally.

The evaluation of the significance of weight measurements must take into account length, frame size, proportions of fat, muscle and bone, and the presence of pathological weight due, for example, to oedema or splenomegaly. Accordingly, weight measurements should be combined with other appropriate measurements and with clinical examination.

Equipment. The choice of suitable scales is a difficult matter. They must be sturdy, inexpensive, easily transportable, and accurate to within the limits required (e.g., 0.1 kg). They must be checked frequently through the complete range of weights envisaged, at least twice daily during a survey,

¹Photography can be a valuable tool for the assessment of nutritional status in the laboratory, as well as under field conditions, but is too expensive and time-consuming to be commonly used, except in a general way. To be of value, anthropometric photography requires adequate standardization of procedure, i.e., posture, avoidance of distortion, uniform lighting, etc. The scale used should always be included in the photograph, and should be located in the same plane as the subject Proper identification is essential.

Measurements from photographs require uniform positioning which is almost impossible to obtain in mass surveys of young children. In older children and adults, valuable anthropometric and clinical information can be obtained. With suitable arrangements, photography can substantially reduce the time required for field measurements. The great advantage of photographs is that one can always return to the original records for checks on doubtful data at a more leisurely pace than is possible under field survey conditions.

Selected photographs can be of considerable value in illustrating nutritional aspects and various features in the local ecology. They are particularly needed to illustrate subjective judgements of health and nutritional status.
by the use of objects of known weight supplied for this purpose. The scales should be corrected in the light of the tests, or—less satisfactorily—allowance made in the results.

Weighing machines based on two different principles are available: beam balance scales and spring scales. The latter should not be used because they easily become stretched and inaccurate from frequent use or with the expansion of the spring that occurs in unduly hot weather.

Beam, or lever, balance scales (Fig. 33) are preferable, as they are less likely to be inaccurate if carefully looked after. Their accuracy depends, however, on the integrity of their knife-edge balancing part or fulcrum. Beam balance scales are usually of the familiar type supplied by UNICEF for young children, measuring up to 16 kg (35 lb) with increments of 100 g (3½ oz) or the platform type for adults or older children. Both are rather heavy to transport and can become mechanically inaccurate after jolting on a rough road journey. The use of a locking device or wedging the moving

FIG. 33. WEIGHING PRE-SCHOOL CHILD WITH STANDARD UNICEF BEAM BALANCE SCALE
parts before journeys is advisable. They must be used on a firm, non-tilted surface, and checked before use.

Another type of scale, employing the beam-balance principle, is the butcher’s steelyard (Fig. 34), which is an ancient, simple and inexpensive weighing apparatus. It is compact and can be easily transported, usually weighing up to 20 kg (44 lb) with an accuracy of up to 0.1 kg. It has to be suspended from the branch of a tree or roof beam, but can be read accurately as there is little oscillation (Welbourn, 1956).

Technique. Young children should be weighed nude. If bells or heavy charms are worn, as in some rural African communities, they should be removed, if permissible and practicable. Otherwise, due allowance should be made for their weight. Scales capable of making small measurements with accuracy are needed for young children, especially for serial measurements.

With due attention to technique, relatively passive infants can be weighed on most of the scales mentioned. The problem is more difficult with larger, more active pre-school-age children. As elsewhere in the world, and especially with apprehensive children in rural tropical surroundings, it is often best to use an adult platform beam balance scale to weigh the mother alone, and then weigh her carrying her child. The advantage of this method is that the child is calmed by the mother, so that time is saved and accurate recordings can be made. The disadvantage is that two weights have to be recorded and the risk of clerical error is doubled. The subtraction required to obtain the child’s weight should not be carried out in the field, but on return to base. However, occasional calculations at the time may serve as a check on the clerical recording of figures.
For schoolchildren and adults, the platform beam balance is most usually employed. Weighing should not be done after a full meal. Theoretically, the bladder should be emptied prior to measurement. In fact, this is rarely done and has little practical significance.

The subjects should stand on the centre of the platform without touching anything else. Shoes should be removed and the minimum clothing worn. For schoolchildren, if the sexes are weighed separately, it is possible for clothing to consist of a pair of drawers or shorts. For adults, especially in field circumstances, weighing usually has to be carried out while they are wearing ordinary clothing. In these circumstances, the average weight of the clothing customarily worn must be determined and due allowance made in the results. Details of this kind must always be recorded in the written reports of surveys.

Standards of reference. As noted earlier, body-weight measurements found in a community can best be compared with locally prepared standards, if such exist, and also with suggested general standards of reference (e.g., the modified Harvard Standards for young children (Annex 1, Tables 1)-(4), (10) and (11)), the Baldwin-Wood Standards for schoolchildren (Annex 1, Tables 8 and 9), and the modified Actuaries Standards for adults (Annex 1, Tables 15 and (16)).

Results. Weight assessment in community investigations in most developing countries is concerned with determining degrees of underweight, principally resulting from varying levels of protein-caloric malnutrition. It is not usually concerned with the detection of obesity.

Body weight is mainly made up of muscle, fat, bone and internal organs, with the addition, in pathological circumstances, of oedema, ascites, massive organ enlargement (e.g., splenomegaly) and even the helminth burden in severe ascariasis.

The interpretation of weights below the standard has to take account of these various components, and it can be critically analysed only if a simultaneous estimation of some of these tissues is also carried out at selected sites, especially subcutaneous fat and muscle mass.

Because of differences in growth at various stages of life, weight levels or changes in weight over a period of time have to be interpreted differently in various age-groups. These are considered in a later section for young children, schoolchildren, pregnant women, and adults.

2. Linear measurements

Two types of linear measurement are commonly employed: (a) height (or length) of the whole body and (b) certain circumferences, particularly of the head and the chest.
Height (or length)

The height of an individual is made up of the sum of four components: legs, pelvis, spine and skull. While, for detailed studies of body proportions, all of these measurements are required, in field nutritional anthropometry usually only the total height (or length) is measured.

Equipment and technique. For older children and adults, a vertical measuring rod or a scale fixed to a wall can be employed (Fig. 35). After removing the shoes, the subject should stand on a flat floor by the scale with feet parallel and with heels, buttocks, shoulders and back of head touching the upright. The head should be held comfortably erect, with the lower border of the orbit in the same horizontal plane as the external auditory meatus. The arms should be hanging at the sides in a natural manner. The headpiece, which can be a metal bar or a wooden block, is gently lowered, crushing the hair, and making contact with the top of the head. The presence of unusually thick hair requires to be taken into account. The measuring scale should be 2 m (78 3/4 in.) high and capable of measuring to an accuracy of 0.5 cm (1/5 in.).

For infants and pre-school children, recumbent length (crown-heel length) has to be employed, as the measurement of standing height is either impossible or very inaccurate with an uncooperative child. This is usually carried out with a wooden length-board (Fig. 36).

The infant is laid on the board which is itself on a flat surface. The head is positioned firmly against the fixed headboard, with the eyes looking vertically. The knees are extended, usually by firm pressure applied by an assistant, and the feet are flexed at right angles to the lower legs. The upright sliding foot-piece is moved to obtain firm contact with the heels and the length read to the nearest 0.1 cm.
The difficulties of using a length-board for measuring terrified, struggling young children in rural surveys are considerable. Much practice and the assistance of two, or preferably three, people are required to make adequately accurate readings.

Standards of reference. Results should be compared with local standards, if such exist, and with general standards of reference (Annex I, Table (2)). The usefulness and the interpretation of this measurement in various age-groups are given in other sections.

Head circumference

The measurement of head circumference is a standard procedure in paediatric practice, usually to detect pathological conditions accompanied by a large head or one of increasing size, as, for example, with hydrocephalus, or too small a skull, as with microcephaly.

Head circumference is related mainly to brain size and—to a small extent—to the thickness of the scalp tissues and the skull. Brain-size increases rapidly during the first year, when head circumference normally reflects age rather than health or nutrition. However, brain-size and both the thickness of scalp soft tissues and the skull can vary with nutritional status, so that head circumference is slightly affected in the second year of life in protein-calorie malnutrition (Robinow & Jelliffe—in preparation), although much less so than chest circumference.

In nutritional anthropometry, the chest/head circumference ratio is of value in detecting protein-calorie malnutrition in early childhood (see page 196). The head circumference may also be used as a rough additional guide in age assessment.

Equipment and technique (Fig. 37). Measurements should be made with a narrow (less than 1 cm wide), flexible, non-stretch tape, made of steel or
preferably fibre-glass. Cloth tapes should be avoided as they tend to stretch in use. If they have to be used, they should be checked frequently.

The child's head should be steadied and the greatest circumference measured, by placing the tape firmly round the frontal bones just superior to the supra-orbital ridges, passing it round the head at the same level on each side, and laying it over the maximum occipital prominence at the back. Measurements should be made to the nearest 0.1 cm.

Standards of reference. Little work appears to have been done in this field among children in different parts of the world. Variations in skull appearance occur in different ethnic groups, presumably on a genetic basis, although the possibility of other factors playing a part in these differences cannot be overlooked. These may include cultural practices in infancy—seen in an extreme form in the head-binding of certain South American Indians, in the large skulls sometimes found in rickets, or in such pathological conditions as sickle-cell anaemia.

Local standards require to be constructed. In the meantime, figures given by Watson & Lowrey (1958) can be used for reference purposes.

Chest circumference

Again, the main practical field use of this measurement will be in the second, and perhaps third, years of life. This is because the circumference of the head and the chest are about the same at six months of age. After this, the skull grows slowly and the chest more rapidly (Table 6). Therefore, between the ages of six months and five years, a chest/head circumference ratio of less than one may be due to failure to develop, or to wasting of the muscle and fat of the chest wall, and can be used as community indicator of protein-calorie malnutrition of early childhood. It also has the advantage of not requiring even a tape measure, as the two circumferences can be compared with a piece of string (Dean, 1965).

Equipment and technique. A narrow, flexible non-stretch steel or fibre-glass tape should be used, and measurement made at the nipple line, prefer-

---

1 Variations in skull shape may be recognized—for example, among the Baganda, who have different words for bossing in different places (e.g., mpumi for frontal bossing, masinya for parietal bossing, and nkoma for occipital bossing).
TABLE 6. HEAD AND CHEST CIRCUMFERENCE MEASUREMENTS IN FIRST FIVE YEARS OF LIFE

<table>
<thead>
<tr>
<th>Age (months)</th>
<th>Head (cm)</th>
<th>Chest (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birth</td>
<td>35.0</td>
<td>35</td>
</tr>
<tr>
<td>3</td>
<td>40.4</td>
<td>40</td>
</tr>
<tr>
<td>6</td>
<td>43.4</td>
<td>44</td>
</tr>
<tr>
<td>12</td>
<td>46.0</td>
<td>47</td>
</tr>
<tr>
<td>18</td>
<td>47.4</td>
<td>48</td>
</tr>
<tr>
<td>24</td>
<td>49.0</td>
<td>50</td>
</tr>
<tr>
<td>36</td>
<td>50.0</td>
<td>52</td>
</tr>
<tr>
<td>48</td>
<td>50.5</td>
<td>53</td>
</tr>
<tr>
<td>60</td>
<td>50.8</td>
<td>55</td>
</tr>
</tbody>
</table>


ably in mid-inspiration (Fig. 38). Practical problems may be considerable, as it is difficult to obtain accurate readings if the child is screaming or breathing irregularly. Consequently, this procedure is best carried out with the child sitting on its mother’s lap. Measurement should be made to the nearest 0.1 cm.

3. Soft tissues

The brain, liver, heart, kidneys and other internal organs together make up an appreciable part of the body weight, but are relatively unchanged by weight in malnutrition. Muscle and fat constitute the soft tissues that vary most with a deficiency of protein and calories. Tissue anthropometry can be carried out on both of these in the assessment of the nutritional status of a community.
Subcutaneous fat

Body composition studies, including information concerning the amount and distribution of human subcutaneous fat, and hence of calorie reserves, can be carried out by various methods, including the following:

- physical and chemical analysis (by whole-body analysis at autopsy)
- ultrasonics
- densitometry (by water displacement in a densitometer, or underwater weighing)
- gaseous uptake of fat-soluble gases
- radiological anthropometry (using soft-tissue exposures)
- physical anthropometry (using skin-fold calipers).

Equipment. While all the techniques listed above can be important tools in detailed nutritional investigation in well-equipped research centres, only physical anthropometry using skin-fold calipers is practicable in field circumstances and, even then, great care has to be taken with the technique employed and with the interpretation of results. It may be noted, however, that the correlation between caliper measurements, radiological findings and direct measurements at surgical operations is good (Tanner, 1959; Garn, 1962).

Various skin-fold calipers have been devised, but experience has shown that the instrument used should have a standard contact surface or “pinch” area (20-40 mm²), should read to 0.1 mm accuracy and exert a constant pressure (10 g/mm²) through the whole range of skin-fold thicknesses at all distances of separation of the jaws.

In practice, three instruments at present seem to be most often used: the Harpenden calipers (Edwards et al., 1955) (Fig. 39) the Lange calipers (Lange & Brozek, 1961) (Fig. 40), and the USAMRNL calipers (Best, 1953, 1954; Consolazio, Johnson & Pecora, 1963). Where possible, the dial must be carefully reset to zero before each day’s work, if practicable, or due allowance made for zero error.

Technique. The skin-folds measured consist of a double layer of skin and subcutaneous fat. The most appropriate “pinch” sites depend on the purpose of the study, the age of the population examined (fat distribution varies with age, even in childhood), sex, precision in locating the particular site, the relative homogeneity of the thickness of the layer of fat and skin in a given region, and the ease or otherwise of accessibility when problems of undressing and modesty exist (Garn, 1957; Lewis, Masterton & Ferres, 1958). The left side of the body should be used for this and all other measurements (Falkner, 1960).

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1 Full documentation of the latest scientific advances in this field are given by Forbes (1962) and by the Annals of the New York Academy of Sciences (1963), Vol. 110 (2 parts).
2 Garn (1962) has pointed out that this supplies a permanent record. It is possible that radiological films taken for orthopaedic reasons in developing regions or elsewhere might be analysed.
3 US Army Medical Research Nutrition Laboratory, Chicago, Ill., USA.
FIG. 39. HARPENDEN SKIN-FOLD CALIPERS

FIG. 40. LANGE SKIN-FOLD CALIPERS
In most large-scale surveys, in both adults and children, major emphasis has usually been on obesity due to caloric overnutrition. With this in mind, workers, including Hammond (1955b), have suggested that total body subcutaneous fat can be calculated from measurements made at several places, such as the triceps, the abdomen, and subscapular and subcostal sites.

Similar methods can be employed in communities in developing regions, but large numbers of measurements will not usually be indicated or feasible. Despite the fact that increase or depletion of subcutaneous fat stores is not uniform all over the body, the essence of the problem is to select one or two easily accessible sites that may be expected to give an approximate practical indication of caloric reserves. For this purpose, both with poor calorie stores and in obesity, the triceps skin-fold is the most practical measurement for all age-groups.

Furthermore, in young children, the triceps skin-fold is not only useful as an index of caloric reserves but enables the underlying mid-upper arm muscle circumference to be calculated (see Fig. 44).

At all sites, a lengthwise skin-fold is firmly grasped and slightly lifted up between finger and thumb of the left hand, care being taken not to include underlying muscle. The calipers are applied about 1 cm below the operator’s fingers at a depth about equal to the skinfold, while the skin-fold is still gently held throughout the measurement. Three measurements should be made and the results averaged. Difficulties in obtaining accurate results can occur because of increased compressibility in frank, or even subclinical, oedema, and possibly because of the normal occurrence of softer fat in infants than in adults.

The technique is by no means easy and requires prolonged supervised practice and repetition to obtain reliable and reproducible results.

Triceps skin-fold (upper arm, dorsal arm, arm skin-fold). As the fat in this region is not uniform in thickness, the site is carefully selected, halfway down the arm, between the tip of the acromion process of the scapula and the olecranon process of the ulna (Fig. 41). The measurement is made with the arm hanging relaxed at the side. The skin-fold parallel to the long axis is picked up between the thumb and forefinger of the left hand, clean away from the underlying muscle, and measured at this point (Fig. 42) (Committee on Nutritional Anthropometry, 1956).

Subscapular skin-fold (infraspinatus, back skin-fold). The subscapular skin-fold is measured just below and laterally to the angle of the left scapula. The fold should be in a line running at approximately 45° to the spine, in the natural line of skin cleavage. It is often used as a secondary site for adults. It has the advantage of providing a uniform layer of subcutaneous fat, not requiring precise localization. It has the disadvantage of inaccessibility.
Standards. With the considerable variation in fat distribution with age, both in early childhood and in later life, separate standards are needed for different age-groups. Likewise, sex differences occur throughout life, with skin-folds greater in females from birth onwards. Also, limb skin-folds, including the triceps measurement, can yield falsely low results if the skin and subcutaneous fat are stretched by considerable underlying muscle hypertrophy.

Appropriate standards for use in communities in developing tropical regions are difficult to lay down with certainty. It is possible that a lesser insulating layer may be usual in warmer climates, and also that figures obtained so far from Europe and North America are too high, reflecting a too-generous calorie intake, which may well not be optimal. Also, a variation in fat composition may occur with different diets and environmental temperatures, possibly associated with atypical physical properties, such as compressibility (MacDonald, 1961; McLaren & Read, 1962), while a genetic difference in subcutaneous-fat distribution has been suggested (Robson 1964b).

It is therefore desirable that local standards should be prepared and compared with those already available from well-fed Caucasian populations. In the meantime, general standards of reference are given in Annex 1, tables (5), (12) and (17).

Muscle

Poor muscle development or muscle wasting are cardinal features of all forms of protein-calorie mal-
nutrition, especially those of early childhood. In older children and adults, muscle mass is also related to general exercise and to special increased use of certain muscle groups.

Muscle mass \(^1\) may be assessed in various ways (Standard, Wills & Waterlow, 1959):

(a) Total: body analysis (at autopsy) (Garrow, Fletcher & Halliday, 1965)
body radio-active potassium (as a measure of cellular mass, of which muscle is the principal component)
chemical urine analysis (for muscle breakdown products, e.g., creatinine excretion)

(b) Localized: soft tissue radiology (of leg or arm)
physical anthropometry (by measurement of a limb).

For practical purposes, with the possible exception of urine samples for creatinine excretion, the only practical field method is by direct physical anthropometry of a limb.

**Technique.** In practice, two limbs have been used—the mid-calf and the mid-upper arm. Both are roughly circular and heavily muscled.

Measurements of the mid-upper arm appear to be most useful in practice. This region is easily accessible, even with a young child sitting in front of the examiner on his mother’s lap. Also, in kwashiorkor the upper arm is not usually clinically oedematous, while it has been shown that the mid-upper arm is markedly wasted in this condition.

The arm circumference is measured to the nearest 0.1 cm with a flexible steel or fibre-glass tape, which must be placed gently, but firmly, round the limb to avoid compression of the soft tissues (Fig. 43). In young infants, it is difficult to measure the small circumference of the arm with a steel tape, and it is necessary to use a glass-fibre one.

The left arm is measured, while hanging freely, at its mid-point, which is selected in the same way as for the triceps skin-fold. Secondly, the overlying subcutaneous fat is measured in the triceps region with skin-fold calipers as described earlier (p. 74).

From these two measurements, it is possible to calculate the inner circle, which is composed principally of muscle, with a small central core of bone. It is usually assumed that the bone is relatively constant in size, and the calculated value is termed the “mid-arm-muscle circumference”.\(^2\) Alternatively, it is possible to make allowance for the humerus by subtracting an approximate standard value according to the age of the subject, but usually this is not done. A formula for the calculation of the mid-arm-muscle

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\(^1\) Measurement of muscular strength by dynamometry is not usually practicable in survey work, as it is time-consuming, influenced by psychological factors, and impossible to use in young children. It may sometimes be of value for adults and schoolchildren.

\(^2\) Alternatively, the I.A.D. (“inner arm diameter”), composed principally of muscle and bone, has been calculated as a gauge of muscularity (McFie & Welbourn, 1962).
circumference is given in the caption of Fig. 44 (based on Jelliffe & Jelliffe, 1960).

An apparent disadvantage of this type of measurement is that it is a linear expression of a three-dimensional tissue, which should, ideally, be given by weight or volume. However, this single measurement cor-

FIG. 44. CALCULATION OF MID-UPPER-ARM-MUSCLE CIRCUMFERENCE

Measurements are made of arm circumference $C_1$ and triceps skin-fold $S$. Let $d_1 =$ arm diameter and $d_2 =$ muscle diameter. Then skin-fold $S = 3 \times$ subcutaneous fat $= d_1 - d_2$, and arm circumference $C_1 = \pi d_1$. Now, muscle circumference $C_2 = \pi d_2 = \pi (d_1 - (d_1 - d_2)) = \pi d_1 - \pi (d_1 - d_2)$. Hence, $C_2 = C_1 - \pi S$. 
relates well with more general manifestations of protein-calorie malnutrition. Also, it is an attempt to assess a body-wide tissue, which may be affected unequally in different muscle groups, by a measurement at a single site. Nevertheless, the arm-muscle circumference does represent a practical, if approximate, gauge of muscle tissue, and one that can be easily obtained.

An even simpler measurement, that of the arm circumference, may be used by itself, because it has been shown to correlate well with the calculated muscle circumference (Robinow & Jelliffe—in preparation) and to be much reduced in all severe forms of protein-calorie malnutrition of early childhood (see page 196).

Standards. Values for arm-muscle circumference are not easily available for well-nourished communities. Approximate general standards of reference are given later for this calculated measurement and also for arm circumference for different ages and both sexes (Annex 1).

Recommended basic measurements for surveys

The following basic measurements should be made on all age-groups: weight, height (or length), triceps skin-fold, and arm circumference.

In young children, these should be supplemented by measurements of the head circumference and of the chest circumference.

BIOCHEMICAL TESTS1

Although biochemical estimations of nutritional significance can be carried out on a variety of body tissues, including liver, muscle (Waterlow & Mendes, 1957) and bone, in practice, in field surveys, tests are confined to two fairly easily obtainable body fluids: blood and urine.

The range of biochemical tests that can be employed for assessing malnutrition is considerable. However, in rural field conditions, this will be limited by many factors, including the need for single-specimen samples, rather than the collection of "timed" samples or the use of loading tests; the age-groups concerned (and the difficulty in securing large samples of venous blood from young children); and the limitation of laboratory facilities, especially of skilled laboratory staff.

Defining ideal criteria for biochemical tests suitable for field work, Whitehead (1965) stresses that these should be easily collectable (this implies a finger-prick sample of blood or a random specimen of urine), stable during transport (preferably not requiring refrigeration), not affected by a recent meal or by water load, and capable of giving information not already available by non-biochemical techniques, so that they can be used either for objective quantitative assessment or as a screening procedure.

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1 This section has been based largely on the report of the WHO Expert Committee on Medical Assessment of Nutritional Status (1963), on the work of Goldsmith (1959) and Wilson et al. (1964), and on the manual prepared by the ICNND (1963). These publications should be consulted for additional technical details, including laboratory control, reproducibility, etc.
Generally, intricate biochemical tests are costly and time-consuming to carry out. In all surveys, the expected value of results to be obtained by particular methods in the assessment of nutritional status must be weighed against the problems of collection, transport, laboratory analysis and interpretation. In addition, while some tests are of considerable assistance, many have as yet uncertain "standards" for less advanced forms of malnutrition, especially in young children. In fact, valuable nutritional surveys of limited scope can be undertaken with a small team by means of clinical assessment, anthropometry, dietary inquiry, and with no laboratory investigation other than haemoglobin estimation.

Appropriate biochemical tests will have to be selected for the particular survey contemplated. The range to be employed may embrace some, or all, of the tests listed in category 1 (Table 7), or may be much more restricted. For a nutrition survey to produce useful information, it is not always necessary to have the large number of personnel and the quantities of equipment required for a wide range of biochemical tests.

Sometimes laboratory investigations may be practicable on a limited sample of those covered by the survey, particularly if specimens can be air-freighted to a regional centre. Selection, again, may be by subsampling, or by choosing subjects considered, on clinical evidence, as likely to be deficient. Thus, more detailed haematological tests may be carried out on only a small percentage of those found to be definitely anaemic by clinical assessment or by haemoglobin level. Also, vitamin "loading" tests with riboflavin may be feasible in a sample of persons with angular cheilosis and other suggestive signs of ariboflavinosis.

As with all methods of assessment, the nutritional significance of the results of biochemical tests in a community has to be correlated with all the other findings—clinical, anthropometric, dietary and ecological.

Collection of samples

Numbers. When the appropriate biochemical tests for the particular survey have been chosen, a decision must be made on the number of specimens that can be collected and processed, since this will determine the required amount of collecting equipment. The number of specimens will depend on statistical considerations in relation to the total number of persons examined clinically in the field and on the limitations imposed by facilities for transport, storage and actual analysis. A sub-sampling technique will normally be required.

Blood samples. Plasma is required for examinations for albumin, vitamin A, carotene, ascorbic acid and alkaline phosphatase, and will have to be prepared from oxalated whole blood by centrifugation. Fresh whole blood or blood preserved with sequestrene is used for the determination of haemoglobin and haematocrit, and for the preparation of thin and thick blood films, if these are to be included.
TABLE 7. BIOCHEMICAL TESTS APPLICABLE TO NUTRITION SURVEYS *

<table>
<thead>
<tr>
<th>Nutritional deficiency</th>
<th>First category</th>
<th>Second category</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Protein</td>
<td>Amino acid imbalance test</td>
<td>Serum protein fractions by electrophoresis</td>
</tr>
<tr>
<td></td>
<td>Hydroxyproline excretion test (F)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Serum albumin</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Urinary urea (F)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Urinary creatinine per unit of time (T)</td>
<td></td>
</tr>
<tr>
<td>(2) Vitamin A</td>
<td>Serum vitamin A</td>
<td>Serum inorganic phosphorus</td>
</tr>
<tr>
<td></td>
<td>Serum carotene</td>
<td></td>
</tr>
<tr>
<td>(3) Vitamin D</td>
<td>Serum alkaline phosphatase</td>
<td>White blood cell ascorbic acid</td>
</tr>
<tr>
<td></td>
<td>(in young children)</td>
<td>Urinary ascorbic acid</td>
</tr>
<tr>
<td>(4) Ascorbic acid</td>
<td>Serum ascorbic acid</td>
<td>Load test</td>
</tr>
<tr>
<td>(5) Thiamine</td>
<td>Urinary thiamine (F)</td>
<td>Blood lactate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Red blood cell haemolysate transketolase</td>
</tr>
<tr>
<td>(6) Riboflavin</td>
<td>Urinary riboflavin (F)</td>
<td>Load test</td>
</tr>
<tr>
<td>(7) Niacin</td>
<td>Urinary N-methylnicotinamide (F)</td>
<td>Red blood cell riboflavin</td>
</tr>
<tr>
<td></td>
<td>(F)</td>
<td></td>
</tr>
<tr>
<td>(8) Iron</td>
<td>Haemoglobin</td>
<td>Serum iron</td>
</tr>
<tr>
<td></td>
<td>Haematocrit</td>
<td>Percentage saturation of transferrin</td>
</tr>
<tr>
<td></td>
<td>Thin blood film</td>
<td></td>
</tr>
<tr>
<td>(9) Folic acid /</td>
<td>Haemoglobin</td>
<td>Serum folate (L. casei)</td>
</tr>
<tr>
<td>Vitamin B12 /</td>
<td>Thin blood film</td>
<td>Serum B12 (E. gracilis)</td>
</tr>
<tr>
<td>(10) Iodine</td>
<td>Urinary iodine (F)</td>
<td>Tests for thyroid function</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Adapted from WHO Expert Committee on Medical Assessment of Nutritional Status (1985).  
\(^a\) Urinary creatinine used as reference for expressing other urine measurements in first category.  
\(^b\) Expressed per gram of creatinine.  
(F) In a single urine specimen, preferably fasting.  
(T) In timed urine specimens.

Blood tests are often carried out with macro-methods, although the relatively large quantities required can be obtained in field circumstances only from adults or school-age children. Venous samples are preferably taken by vacuum tube (such as the Vacutainer), or with disposable needles attached to plastic tubing, to avoid contamination and the need for cleaning and sterilizing syringes in the field. The latter is the easiest and cheapest method of obtaining blood samples, especially if used with a sphygmomanometer rather than a tourniquet, and it also permits several samples of blood to be taken into different containers during one venepuncture, if required.

Equipment for washing out and unplugging syringes and needles must be immediately at hand when samples are taken. Needles must be sharpened
as necessary. The technique for drawing blood must be thoroughly known and practised.

Blood samples are collected into stoppered or screw-capped glass vials, containing an anticoagulant, such as dried oxalate or heparin lithium. Each container should have a previously affixed blank label.

Some of the biochemical tests used for nutritional appraisal can be carried out by micro-methods. These methods are particularly important where young children are concerned. Blood obtained by finger-prick can be collected in heparinized capillary tubes, and sealed by heating in a flame or by using commercial clay, specially prepared for this purpose.

All blood samples must be kept chilled until tested. In the field, this is achieved in thermos flasks, in plastic cooling bags (with tins of freezing mixture) or, rarely, in mobile refrigerators. In the laboratory, the specimens are kept in an ordinary household refrigerator.

Urine samples. Difficulties in collection from adults are largely related to modesty. For young children, only boys can have this undertaken easily by fixing a test-tube (preferably of plastic) to the penis, although a relatively expensive plastic disposable collecting device, which sticks to the perineum, can be used for little girls. Sometimes, however, it may suffice for plastic jars to be given to mothers for them to "catch" a specimen during the survey period.

For the commoner urinary analyses (e.g., urea, thiamine, riboflavin, N-methyl-nicotinamide), fasting samples passed in a definite time-period are ideal, but not usually practicable under field conditions, especially with children. Single random specimens must often suffice. However, when used as a measure of body-muscle mass, urine for creatinine estimation has to be collected over a timed period—minimally 3 hours, and preferably 24 hours.

Urine should be collected in sturdy screw-capped glass or, preferably, plastic bottles containing hydrochloric acid as a preservative and as an inhibitor of bacterial growth. The amount of hydrochloric acid should be such as not to dilute the sample greatly: one drop of concentrated hydrochloric acid should be enough for about 25 ml of urine. The specimen can then be kept at room temperature or stored in a refrigerator.

Laboratory considerations

Site. The various laboratory tests differ in complexity in respect of the staff and facilities required, and the time within which they have to be performed once the sample has been taken.

One, or all, of three laboratory sites have to be considered:

(a) survey site facilities for taking, labelling, packaging and refrigerating samples;
(b) a field laboratory adjacent to, or not far distant from, the survey site. Adequate bench or table space should be available, as well as a water supply, a refrigerator, cylinders of gas and, if possible, electricity;

c) a base laboratory, often situated in a central institution, such as a medical school or an agricultural research station.

The most suitable arrangement for a given survey depends upon the tests envisaged, the availability and location of existing laboratories, the distances and communications involved, and the funds available. In some surveys, it may be possible to build up a new laboratory, or to help one develop or expand.

In most developing countries, laboratory services are limited outside main centres, and plans must be made to take most of the samples back at the end of a survey, or to send them at intervals during the field work, depending on local circumstances. The necessary funds for staff, including drivers, and for equipment, including refrigeration, must be budgeted for in whatever scheme is considered to be appropriate.

In many shorter surveys, it is easier and more economical to make it a rule that, whenever possible, specimens should be collected in the field, preserved or refrigerated suitably, and ultimately taken back to the base laboratory at the end of the survey.

Equipment. Initial and recurrent equipment needed must be calculated as far as possible on an estimate of the numbers of samples likely to be collected and their possible storage and transport. A 20% excess is desirable for field work to cover breakage, loss and any initial underestimate of attendance.

Supplies should be standardized, as far as possible. Containers should be labelled prior to the field work and held ready for use (e.g., with anticoagulants already in them). They should be as strong as possible and of suitable shape to facilitate packing and minimize breakage (e.g., sturdy, flat-bottomed, thick-glass or plastic, screw-capped vials).

Techniques. Laboratory techniques must be selected for their accuracy, sensitivity, reproducibility, and practicability within the technical resources available. Methods commonly used and of proved value are suggested in subsequent sections dealing with individual nutrients. In all cases, the method employed must be described in reports, and, if it is a modification of a standard procedure or a new technique, details must be given.

Details must also be given of procedures used in the collection, transport and storage of specimens, including, if relevant to the particular tests, the time when taken, possible exposure to sun, heat and air, and the period between collection and testing. Interpretation of biochemical tests

The significance and accuracy of results of biochemical tests are related to standards of collection, methods of transport and storage, including
possible exposure to ultraviolet light, heat and shaking, and the actual
technique used including laboratory control using control sera (Sinclair,
1964).

The interpretation of results varies with knowledge of the unique
metabolism of each particular nutrient, including its storage in the body, the
possibility of synthesis and the mode of excretion. The tests employed
usually assess one of two aspects of nutritional inadequacy, although their
specificity may be less than is at present appreciated.

First, a biochemical investigation may give information on the nutrient
supply to the body, as reflected by levels in a particular tissue, most often
the serum, e.g., ascorbic acid. However, the concentration of an essential
nutrient in a body fluid may be reduced as a result of dietary deficiency,
poor absorption, impaired transport (as can result from the decreased
plasma proteins in protein-calorie malnutrition), abnormal utilization, or a
combination of these. The presence of haemoconcentration, as in dehydration,
or of haemodilution, as in pregnancy, requires consideration. While
the measurement of nutrient concentration is helpful in suggesting the possibility of malnutrition, it does not indicate the presence, or define the
degree, of nutritional disease.

Secondly, some biochemical tests can be undertaken that reveal metabolic
changes resulting from tissue malnutrition due to inadequate levels of
essential nutrients, often of long duration. The detection of such metabolic
changes aids in the assessment of nutritional status and, in many instances,
indicates a state of deficiency with greater certainty than does a mere
lowering of tissue concentration of essential nutrients. Furthermore,
these changes sometimes precede the appearance of clinical manifestations
of malnutrition. However, in some instances, biochemical tests relate to
both the causes mentioned.

In addition to interpretation in relation to biochemical significance,
levels of nutrients in the body have to be compared with the standards of
reference, if possible, appropriate for the age and sex. Often these will
have been constructed from results from the normal range found in well-
fed healthy groups and from results from patients obviously clinically ill
with the particular form of malnutrition. In such circumstances, it may be
possible to sort out the findings into various highly tentative groups, with
descriptive labels, such as "deficient", "low", etc. (Tables 8 and 9).

Often, however, standard values are not known, especially for children.
The results then are necessarily expressed in relation to whatever data are
available, even though the age-group is inappropriate.

Whether there is sufficient information to sort into specific "labelled"
groups or not, it is always necessary in addition to report results mathe-
matically, including the number examined and the results expressed as
means (averages), standard deviations, and in numbers and percentages in
convenient groups.
Tests for specific nutrients

Although it may sometimes be difficult to find a biochemical test that will determine the presence of one specific nutrient, certain tests can be regarded as having some degree of specificity or, rather, indicativeness. From the practical point of view, these tests may be divided into two categories (Table 7):
First category. Those which have been most extensively used in past nutrition surveys and have a demonstrated usefulness. The necessary samples are relatively simple to collect, and the tests are easy to carry out in general nutrition laboratories. The urine tests included can be carried out on a single specimen.

Samples of blood and urine are preferably collected from subjects in the fasting state, but as this is not usually practicable, the investigator may have to resort to random specimens.

Second category. Methods of performing the tests in this category are complicated and are based on samples that are difficult to collect. In addition, the methods used are designed, in most instances, to gain more accurate and specific knowledge of particular nutritional inadequacies suggested by first-category tests, as well as by other survey data. They will be employed only in research investigations. They are set out in Annex 2.

The following sections are concerned with the commoner biochemical methods of assessing nutrient intake and nutritional status that have proved to be most applicable to nutrition prevalence surveys. References to commonly used biochemical procedures are also given in the text.

1. Proteins

Biochemical tests may be employed to test three aspects of protein nutrition:

(a) the relative adequacy of dietary intake;
(b) metabolic changes due to tissue malnutrition; and
(c) depletion of body stores of protein.

Dietary adequacy

The urea-nitrogen/creatinine-nitrogen excretion ratio is an approximate index of dietary protein related to muscle protein stores, although the result is affected by the preceding water load (Arroyave, Jansen & Torrico—in preparation). Although a 24-hour collection period probably gives more reliable results, a 3-4-hour period has been suggested (Powell, Plough & Baker, 1961). Once again, the collection of samples may present difficulties in the field (Luyken & Luyken-Koning, 1960). Recently, Dugdale & Edkins (1964) have suggested that an index of 30 or lower in a random sample is indicative of malnutrition.

The estimation itself is simple to carry out using an adaptation of the picrotate method of Folin & Wu (1919) given by Consolazio, Johnson & Marck (1951), or by micro-methods (Toal & Daniel, 1950). Urea can be estimated in many ways; the method of Archibald (1945) is often used.
Metabolic changes

Alterations in amino acid metabolism have been demonstrated in kwashiorkor. They are probably due both to widespread metabolic changes, possibly caused by enzyme defects, and to immediate inadequacy of dietary protein. Thus, Holt et al. (1963) have shown that "plasma aminograms" from hospitalized cases of kwashiorkor in many parts of the world showed a similar pattern—namely, a reduction in most of the essential amino acids and certain inessential amino acids, and unaffected, or even high, values for most of the inessential group.

Recently, a new abbreviated test for imbalance of amino acids in the serum has been introduced that promises to be of value in survey work (Whitehead, 1964, 1965; Whitehead & Dean, 1964; McLaren, Kamel & Ayyoub, 1965). It consists in separating and assessing quantitatively four "indispensable" amino acids (leucine, isoleucine, valine, methionine) and four "dispensable" amino acids (glycine, serine, glutamine, taurine), by one-dimensional paper chromatography.

This test has the advantage that it is carried out on a capillary tube of blood obtained from a finger-prick, which has to be centrifuged immediately, but is stable for some days at room temperature thereafter, although preferably kept cool at icebox temperature (5°C) (Whitehead, 1965). It must not be frozen or haemolysis will occur. The test has the added merit of being independent of age.

Disadvantages include the need for chromatographic apparatus, although this can be quite easily used by specially trained junior laboratory technicians, and the fact that the test is normal in children in the marasmus "line of development". Also, the test is invalidated by a recent high-protein meal, but this effect can be minimized by taking the specimen after a wait of four hours at the collecting point. Such a meal is in any event unlikely in the case of pre-school children in developing regions.

The result is expressed as a ratio of dispensable to indispensable amino acids which is high (5-10) in kwashiorkor and low (less than 2) in well-fed, healthy pre-school children. Initial studies also suggest that the ratio increases between these two levels with the degree of protein-calorie malnutrition in less affected children in the kwashiorkor "line of development", and in particular it correlates with the only simple objective criteria—weight for age. Recent studies by Whitehead (1965) have suggested the following levels: below 2, "ideal"; 2-3, "doubtful"; above 3, "abnormal". This test plainly merits further field trial; so far, it seems to be of value only in the kwashiorkor line of development (see Fig. 53).

More recently, Whitehead (1965) has introduced another test for marginal malnutrition based on the urinary excretion of hydroxyproline, which is low in malnourished children, being a product of collagen metabolism. In field surveys, random samples of urine are collected, and the
hydroxyproline excretion is correlated to creatinine content per kilogram of body weight. Indices for normal children range between 2.0 and 5.0 (mean 3.0), and there is little variation between 3 months and 7 years of age. Clinically malnourished children have indices between 0.5 and 1.5 (mean 1.0), and in marginally malnourished children the values range between 1.0 and 2.0. Abnormal values are found in children deficient in both protein and total calories (nutritional marasmus), so that Whitehead (1965) has suggested that the measurement of both the amino-acid ratio and the hydroxyproline index may be of value in determining the diet of communities of marginally malnourished children.

A similar approach has been suggested independently by Picou et al. (1965).

Depletion of body stores

The plasma proteins, especially albumin, are much reduced in kwashiorkor. However, it is generally agreed that the body's ability to synthesize serum albumin is affected relatively late, and that the primary effect of protein lack is depletion of muscle tissue. Levels of total plasma protein are even more difficult to evaluate, as raised globulin levels, due to infections, including chronic malaria, are likely to influence the results.

It is usually believed that the level of serum albumin falls significantly only in severe protein depletion, thus serving "only as a confirmation of a condition already clinically evident" (Arroyave, 1961), and that it is not of value for detecting "marginal" mild-moderate cases (Waterlow, 1963).

Nevertheless, it must be admitted that investigations among children with protein-calorie malnutrition have mostly been concerned with total plasma proteins in hospitalized children. It does seem justifiable to reinvestigate the usefulness of serum albumin levels in community studies (Schendel, Hansen & Brock, 1960; Woodruff & Pettit, 1965), although it cannot be considered an established procedure in general surveys.

Further comparative studies between plasma albumin and other parameters of protein-calorie malnutrition disease are needed, based on field work, when results should be reported in various levels in grams per 100 ml (e.g., up to 2 g, 2.1 to 3 g, 3.1 to 4 g, 4.1 to 5 g, and over 5 g).

This test has the advantage of simplicity. Total protein can be carried out on a small quantity of serum by a modified Biuret method (ICNND, 1963), and the serum albumin estimated afterwards by paper electrophoresis.

Urinary excretion of creatinine during a timed period—as a minimum, 3 hours, but preferably 24 hours—is considered to be roughly proportional to the body's muscle mass in man (Stearns et al., 1958) and in sheep (Van Niekerk et al., 1963), although unexplained variations in excretion can occur from time to time (Forbes, 1962). Moreover, the intake of flesh foods can affect results, but this will have little significance in most tropical communi-
ties, especially in children. This technique has been used from the converse point of view—that is, for the assessment of obesity in adults (Garn & Clark, 1955) and schoolchildren (Talbot, 1938).

According to Clark et al. (1951), the creatinine coefficient (mg of creatinine excreted per 24 hours per kg body weight) is 22.0 (range 14.2-32.0) from birth to 24 months of age, and 25.0 (range 16.3-36.2) in subjects aged between 2 and 18 years. Oomen (personal communication, 1965), however, found lower figures for young healthy adults in the Netherlands—males and females, 19 mg—and for “normal” young adult sweet-potato eaters in New Guinea—males, 17 mg; females, 14 mg.

The expression of results as “mg of creatinine in 24 hours per cm of body height” is to be preferred to “per kg of body weight,” since variations in fat deposits affect the latter (Arroyave & Wilson, 1961).

Further research tests are given in Annex 2.

2. Vitamin A

Vitamin A is stored in the liver, and a direct assessment of body reserves can be made on liver biopsy material, but this is not practicable under field conditions.

The most useful biochemical test for survey work is the actual estimation of serum vitamin A, especially in young age-groups. However, because of hepatic storage of this vitamin, a low serum level reflects not only an inadequate recent intake, but also exhaustion of liver reserves. It is therefore related to prolonged severe dietary deficiency—probably of up to one year in adults and of up to four months in young children.

It has been shown that low levels of serum vitamin A are found in acute infections (McLaren, 1966) and in kwashiorkor; these low levels are probably due in part to liver dysfunction and in part to impairment of blood transport of the vitamin (Arroyave et al., 1965). Caution may therefore also be required in interpreting results in populations among whom lesser degrees of protein-calorie malnutrition are common (Leonard—personal communication, 1964). In addition, high levels of beta-carotenoids interfere technically with the estimation of serum vitamin A.

In young adult males, the following levels of serum vitamin A have been suggested: “low”, 10-19 mcg; “deficient”, < 10 mcg (ICNND, 1963). Similar standards may be used arbitrarily for all age-groups, although more data are required for pre-school children. In all investigations due attention must also be given to correlation with food-consumption studies, with clinical signs suggestive of avitaminosis A, and, in older children and adults, with results of dark-adaptation tests, if practicable. It seems probable that low serum-vitamin-A levels and abnormal dark-adaptation tests usually antedate the appearance of clinical signs as community indicators of inadequate vitamin-A nutrition.
Serum-carotene estimations are of less value as they merely reflect levels of dietary intake of carotene-containing foods and their digestion and absorption by the body. They are not indicative of vitamin-A nutrition as such, particularly as some are not utilizable by the body (McLaren, 1966). At best, low levels are related to a low intake of carotene-containing foods, which is often important in tropical populations whose diet is deficient in pre-formed vitamin A.

Again, for young adult males, serum-carotene levels can be tentatively classified as "low" if they are less than 40 mcg per 100 ml and acceptable if they are above this figure (ICNND, 1963). Estimations are made by spectrophotometry, using either macro- or micro-methods (Consolazio, Johnson & Marck, 1951; ICNND, 1963).

3. Vitamin D

Adequacy of vitamin-D nutrition is not related to dietary intake alone, because body synthesis can produce part or all for the daily needs, provided that the skin is exposed to sufficient sunlight.

In severe shortage of vitamin D—manifested as rickets in young children and as osteomalacia in adult women—an excessive, though incomplete, bone development is associated with a rise in alkaline phosphatase enzyme in the serum.

In young children, the normal serum alkaline phosphatase ranges between 5 and 15 Bodansky units per 100 ml, and in clinical rickets it usually rises to above 20 units. Similarly, in osteomalacia in adult women, the serum alkaline phosphatase is above the usual adult level of 3 to 5 Bodansky units.1

The serum-alkaline-phosphatase level in groups of children is not a generally accepted criterion for the detection of subclinical deficiency of vitamin D, as it is too unreliable in the early stages. Caution in interpreting findings is also necessary because this enzyme has been shown to be reduced in kwashiorkor (Dean & Schwartz, 1953) and appears to be affected in lesser degrees of protein-calorie malnutrition (Mannheimer, 1966).

Surveys of young children principally concerned with vitamin-D deficiency should be based on a combination of clinical signs, serum-alkaline-phosphatase levels, and radiological examinations.

4. Ascorbic acid 2

The simplest biochemical test for inadequate vitamin-C nutrition is the serum-ascorbic-acid level. Unfortunately, this reflects only the recent

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1 Usual upper limits in King-Armstrong units are 20 units for children and 13 units for adults.
2 A biological screening test for tissue ascorbic acid, using sodium dichloroindophenol solution, has been introduced by Cheraskin, Ringsdorf & El-Ashiry (1966) and may be useful for survey work.
dietary intake. Even an absence of serum ascorbic acid is not diagnostic of scurvy, as volunteers on a vitamin-C-free diet had an absence of serum ascorbic acid for some three months prior to developing clinically evident disease (Grandon, Lund & Dill, 1940). For young adults, 0.10-0.19 mg per 100 ml is regarded as “low” (ICNND, 1963).

The ascorbic acid can be estimated by the dinitrophenylhydrazine method (ICNND, 1963), or by the micro-methods either of Lowry, Lopez & Bessey (1945) or of Raoult (1947). Further research tests are given in Annex 2.

5. Thiamine

Thiamine concentrations in the plasma, red blood cells and white blood cells cannot be determined with small samples, because available methods are not sufficiently sensitive (Burch et al., 1952). However, estimations of urinary excretion of thiamine have been undertaken widely and reflect the intake of this nutrient. The 24-hour output, the one-hour excretion on fasting, or the thiamine content of a random sample per gram of creatinine can be used. Tentative guide figures for thiamine excretion for adults and children are given in Tables 8 and 10.


<table>
<thead>
<tr>
<th>Age (years)</th>
<th>&quot;Low&quot; thiamine excretion (mcg/g creatinine)</th>
<th>&quot;Deficient&quot; thiamine excretion (mcg/g creatinine)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-3</td>
<td>120-175</td>
<td>&lt;120</td>
</tr>
<tr>
<td>4-6</td>
<td>85-123</td>
<td>&lt;85</td>
</tr>
<tr>
<td>7-9</td>
<td>70-180</td>
<td>&lt;70</td>
</tr>
<tr>
<td>10-12</td>
<td>60-180</td>
<td>&lt;60</td>
</tr>
<tr>
<td>13-15</td>
<td>50-150</td>
<td>&lt;50</td>
</tr>
</tbody>
</table>

* Adapted by permission from Pearson (1960).

6. Riboflavin

In field surveys, riboflavin may be determined in a single random urine specimen, preferably collected from a fasting subject. The following standards for young adult males have been suggested (ICNND, 1963):

- riboflavin per 6 hours: “low” 10-29 mcg, “deficient” <10 mcg
- riboflavin per gram creatinine: “low” 27-29 mcg, “deficient” <27 mcg.
Normal values for young children are uncertain, although it is stated that excretion is 2-3 times as great as in adults when expressed per gram of creatinine (Table 11).

Urinary riboflavin can be estimated by the method of Morell & Slater (1946). Further research tests are set out in Annex 2.

**Table 11. Tentative Guide for the Interpretation of Riboflavin Excretion in Children**

<table>
<thead>
<tr>
<th>Age group (years)</th>
<th>&quot;Low&quot; riboflavin excretion (mcg/g creatinine)</th>
<th>&quot;Deficient&quot; riboflavin excretion (mcg/g creatinine)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-3</td>
<td>150-499</td>
<td>&lt;150</td>
</tr>
<tr>
<td>4-6</td>
<td>100-299</td>
<td>&lt;100</td>
</tr>
<tr>
<td>7-9</td>
<td>85-269</td>
<td>&lt;85</td>
</tr>
<tr>
<td>10-15</td>
<td>70-199</td>
<td>&lt;70</td>
</tr>
</tbody>
</table>

* Adapted by permission from Pearson (1962).

7. Niacin

This water-soluble vitamin differs from others of the B complex because an amino acid, tryptophan, serves as its precursor in man, and because it is not secreted in the urine as such, but is metabolized to at least two derivatives, N'-methylnicotinamide and N'-methylpyridone.

In field surveys, excretion of these niacin metabolites in the urine over a timed interval—e.g., 6 hours, or, more usually, in a single random (preferably fasting) urine sample, expressed per gram of creatinine, provides information concerning the dietary intake of niacin and tryptophan.

As about equal quantities of the two metabolites are excreted, an assay of N'-methylnicotinamide is recommended, as this is technically less time-consuming than an assay of N'-methylpyridone. The suggested levels of urinary excretion for young adult males are:

- N'-methylnicotinamide per 6 hours: "low" 0.2-0.59 mcg, "deficient" < 0.2 mcg
- N'-methylnicotinamide per gram creatinine: "low" 0.5-1.59 mcg, "deficient" < 0.5 mcg.

Assessment is made photocolorimetrically by the method of Carpenter & Kodicek (1950). Further research tests are set out in Annex 2.

8 and 9. Iron, Folic Acid and Vitamin B₁₂

Anaemia can occur from deficiency of various nutrients (Wadsworth, 1959). The principal ones are iron, folic acid and vitamin B₁₂.
Iron deficiency may exist in the body as a result of inadequate dietary intake, poor absorption or excessive loss (especially as a result of severe hookworm infection), or a combination of these. This is especially likely to happen in early childhood, when the iron needs are high and the foods eaten tend to be poor sources of this metal.

Possible early effects of iron lack upon the body’s enzyme systems and myoglobin synthesis are not at present measurable, so that the detection of an iron-deficiency anaemia is the only practical method of assessing an iron lack.

In field surveys, this can be best undertaken by haemoglobin estimations, associated with the examination of thin blood films and haematocrit estimations, if practicable.

The haemoglobin can be estimated in various ways, using, for example, the grey wedge photometer, the Spenser haemoglobinometer, or the battery-operated haemoscope (Lewis & Carne, 1965). These three methods are especially indicated if the estimations have to be carried out in the field. The Talquist and Sahli methods are too inaccurate to be recommended, and the results expressed in figures give a false impression of scientific precision.

The cyanmethaemoglobin method is often suitable (Cannon, 1958). In this method, 0.02 ml of fresh or oxalated blood, obtained by finger- or heel-prick without squeezing, is added to 4 ml of Drabkin’s cyanide-ferricyanide solution, which acts as a preservative, if protected from the sunlight, and which also allows the resulting cyanmethaemoglobin to be estimated colorimetrically with an electrical photometer at leisure on return to base, or even days later. If kept over a week, however, flocculation or fungus infection can occur. The photometer requires careful testing and calibration. It can be worked off a car battery.

A field modification of this test has been suggested by workers in Thailand in which the blood (0.02 ml) is run on to a strip of Whatman filter paper (2 cm x 4 cm) and allowed to dry. Specimens can be transported in small individual envelopes, and ultimately dissolved for 30 minutes in the Drabkin’s solution and estimated in the usual way. In the climatic conditions of Bangkok, filter paper specimens can be used up to 10 days after collection (Sundharagati & Harinasuta, 1964).

Standards of haemoglobin suitable for the particular age-groups will have to be applied, while adjustment may be required for altitude. Suggested levels are shown in Table 12.

Haemoglobin levels are independent of climate, but attention may have to be paid to the effects of high altitude, as well as to other possible causes of anaemia, such as malaria, sickle-cell disease and folic-acid deficiency.

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1 The International Committee for Standardization in Haematology recommends that only methods based on estimation of cyanmethaemoglobin or oxyhaemoglobin should be used (British Medical Journal, 1965).
TABLE 12. HAEMOGLOBIN LEVELS BELOW WHICH ANAEMIA CAN BE SAID TO EXIST, AND ASSOCIATED PACKED CELL VOLUMES (PCV %) FOUND IN IRON DEFICIENCY *

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Sex</th>
<th>Hb (g/100 ml)</th>
<th>PCV %</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5-4</td>
<td></td>
<td>10.8</td>
<td>32</td>
</tr>
<tr>
<td>5-9</td>
<td></td>
<td>11.5</td>
<td>53</td>
</tr>
<tr>
<td>10-14</td>
<td></td>
<td>12.5</td>
<td>37</td>
</tr>
<tr>
<td>Adults</td>
<td>Male</td>
<td>14</td>
<td>42</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>12</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td>Pregnant female</td>
<td>10</td>
<td>30</td>
</tr>
</tbody>
</table>


The thin blood film, stained with Wright’s stain, can be examined for cell morphology, especially for the presence of characteristic microcytes, hypochromia, anisocytosis and poikilocytosis.

Megaloblastic anaemias, due to folic-acid or vitamin-B12 deficiency, are suggested by a low haemoglobin, associated with a thin film showing macrocytes, hypersegmented (5-7 lobed) neutrophil polymorphs and reduced numbers of platelets.

Haematocrit estimations are practicable in some surveys, especially if micro-methods are used (Guest & Siler, 1934). A capillary tube of blood is centrifuged at 3000 r.p.m. on an electrical micro-haematocrit which can, if required, be run off a car battery. With young children, when fresh blood is used from a finger-prick, this has to be done as soon as possible, so that a separate “station” with one or two persons will be required to carry out the centrifuging and to measure the results. Packed-cell-volume readings suggestive of iron-deficiency anaemia are given in Table 12.

Results of community surveys should be expressed in relation both to “anaemia levels” (Table 12) and to spaced levels of haemoglobin—for example: up to 4 g/100 ml; 4.1-7 g/100 ml; 7.1-10 g/100 ml; 10.1-12 g/100 ml; over 12 g/100 ml. At times it may also be useful and practicable to classify different levels of haemoglobin “functionally”—that is, in relation to the type of management required—e.g., hospitalization, various types of therapy, close observation, etc.

If community anaemia surveys are to be carried out in a more complete manner, in many tropical regions the following range of tests will be required, especially in children: haemoglobin, thin blood film, micro-haematocrit, thick blood film (stained with Giemsa to show intensity of infection with malarial parasites), a second thin blood film (stained with cresyl blue for
reticulocytes, a stool sample (taken from young children with a glass anal tube, stored in 10% formal saline as a preservative and later examined for occult blood, for the ova of hookworm, and for a rough gauge of approximate worm burden). In African populations, a test for sickling should be included. This may be done by the standard method of a coverslip ringed with vaseline and examined 24 hours later in the field, and by micro-electrophoresis of the packed cells remaining in the capillary tube after micro-haematocrit estimations have been made.

Community anaemia surveys may often best be based on widespread haemoglobin estimations and thin blood film examinations, with subsampling for more complex tests, and with appropriate therapeutic trials, both on severely affected individuals and in the community itself (Stott, 1960).

Further research tests are given in Annex 2.

10. Iodine

A decreased availability of iodine to the thyroid may be the result of an inadequate intake, or possibly of goitrogenic factors in the food.

Field surveys are usually based entirely on the detection of the principal physical sign of iodine lack—thyroid enlargement, especially in accessible age-groups likely to be affected, e.g., schoolchildren, pregnant women.

Further research tests are given in Annex 2.

BIOPHYSICAL METHODS

Radiographic Examination

While routine radiographic studies of population groups are rarely possible, or indeed required, it is sometimes valuable to carry out these investigations on a sample of a population if the physical signs and other circumstances suggest that rickets, osteomalacia, fluorosis or beriberi may be present. This type of survey may also sometimes be of value in the retrospective assessment of malnutrition, as with rickets and possibly protein-calorie malnutrition in early childhood. In such circumstances, the following are the principal signs sought:

Rickets

(a) Active: widened concave (cupped), rarefied, frayed distal ends of long bones, usually the radius and ulna;

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1 This section is based largely on WHO Expert Committee on Medical Assessment of Nutritional Status (1963), p. 26.

2 Recent evidence suggests that transverse trabeculation at the growing ends of long bones in young children may be a result of protein-calorie malnutrition (Platt & Stewart, 1962; Stewart, 1965). Garn and his associates have stressed the measurable degrees of osteoporosis and reduction of compact bone (Garn, 1966).
(b) Healed: concave line of increased density at distal ends of the long bones, usually the radius and ulna.

**Osteomalacia**

Deformity and loss of density of bones, especially the pelvis.

**Infantile scurvy**

(a) Loss of density, ground-glass appearance of long bones;
(b) Line of increased density, sometimes with lateral spur formation due to increased calcification of metaphysis, with underlying zone of rarefaction, usually best seen at the knee.

**Beriberi**

Increased cardiac size.

**Advanced fluorosis**

Increased density of bones, with coarse trabeculation and thickening of the cortex; calcification of ligaments; osteophytic outgrowths at tendinous insertions, and marginal lipping of vertebrae. Changes most marked in the spine (Grech & Latham, 1964).

**Tests of Physical Function**

The main purpose of biophysical tests is to assess alterations in function associated with inadequate nutrition. Many tests have been devised to determine deviations in visual acuity, dark-adaptation of the eye, capillary fragility, nerve accommodation, physical performance (dynamometry, etc.), muscle co-ordination, and so on, in different deficiency states. Their nutritional significance has been critically discussed by Sinclair (1948), who points out that most of them have an uncertain value. They are not usually of practical importance in survey work, although dynamometry was used in the classical study of Orr & Gilks (1931).

Of these tests, dark-adaptation is the most widely used. Although this measurement can be valuable in the objective evaluation of the complaint of night-blindness, one of the causes of which is vitamin-A deficiency, it has several limitations (Kinney & Follis, 1958). The main drawbacks are: (a) tests of dark-adaptation are not a specific measure of vitamin-A deficiency and other factors responsible for its impairment are difficult to eliminate; (b) it is not easy to conduct them in certain age and population groups; and (c) responses to the tests are not entirely free from subjectivity. In spite of all these difficulties, dark-adaptation measurements are of value in special circumstances—for example, in epidemics of night-blindness where the authenticity of the complaint itself needs to be established.

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1 This section is based largely on WHO Expert Committee on Medical Assessment of Nutritional Status (1963), p. 27.
Cytological Test

The examination of stained epithelial smears obtained from the buccal mucosa has been suggested by Squires (1965). Results in malnourished children and experimental animals suggest that the percentage of cornified cells increases with the degree of protein-calorie malnutrition present. Cornified and non-cornified cells can be differentiated by the colour reaction to Schorr's stain (Schorr, 1941).

Buccal smears from healthy children show 60-70% non-cornified cells, while in protein-calorie deficiency this proportion drops to about 20% or less (Squires, 1965).

Further field testing is required. If of confirmed value, the test may be important because it is independent of age. Present evidence suggests that the test may not be positive in marasmus. The effect of other conditions likely to produce changes in the buccal mucosa requires investigation, including febrile illnesses, dehydration and vitamin-A deficiency.