Observations on the Natural History of Stunting

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The reason for organizing this workshop is very simple. If we use a low weight for age as the basis for the anthropometric diagnosis of malnutrition, then in many countries some four-fifths of the children considered to be malnourished are simply small in size, with normal weight for height (Table 1). However, it is remarkable that there has been no systematic attempt to tackle the question: Is it meaningful or realistic to call these small children malnourished? To establish a valid definition, we must avoid a circular argument: nutritional status is assessed by measurement of body size; therefore, a small child is malnourished.

The question posed above is of great public health importance, and attempts to answer it will bring us into difficult territory. It may be useful to divide the question into two parts. First, does smallness imply any impairment of health or functional capacity? More precisely, what are the relationships between body size and different functions after interfering factors have been removed (if, indeed, they can be removed)? Here we are dealing with the *mal* in malnutrition. The second part of the question is whether the effects are caused primarily by nutritional factors and, if they are, by what mechanism? The chapters in this volume are addressed to different aspects of these two questions. These in turn encompass a third question: Does stunting represent a situation that calls for action in countries where resources are scarce, and, if so, what kind of action?

### TABLE 1. Prevalence of malnutrition (percentage) in preschool children according to different criteria*

<table>
<thead>
<tr>
<th>Criterion of malnutrition</th>
<th>Nepal</th>
<th>Sri Lanka</th>
<th>Vietnam refugees</th>
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<tbody>
<tr>
<td>Wasted, stunted, or wasted and stunted</td>
<td>56.2</td>
<td>37.1</td>
<td>65.7</td>
</tr>
<tr>
<td>Wasted or wasted and stunted</td>
<td>7.3</td>
<td>6.6</td>
<td>10.8</td>
</tr>
<tr>
<td>(excluding children who are stunted only)</td>
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*Cut-off points: wasted, <80% of reference median; Stunted, <90% of reference median.
I introduced the term stunting some 10 years ago (1,2) to describe what one actually sees: a deficit in attained length or height of children compared with international standards. It is not a very pleasant-sounding word, and it is difficult to translate into other languages, but at least it is concise and objective. Moreover, it is very convenient that in English we can distinguish between stunting, which is a process and could be regarded as a velocity term, and stunted, which in Tanner's terminology is a distance term. One cannot make this distinction with the word "short." Moreover, "stunted" conveys the impression that the child does not have to be short, that something has gone wrong. However, it is not justified to take the further step of equating stunting with chronic malnutrition, because that begs all the questions raised above.

NATURAL HISTORY OF STUNTING

By natural history I mean the evolution of stunting in time as opposed to its geographical prevalence, which is described elsewhere in this volume by Keller. I concern myself with two particular questions: When does stunting begin in the populations with which we are concerned? What are the possibilities for catch-up? Obviously, there are many other matters that are relevant to the natural history, but they are discussed in other chapters.

At the beginning there is the problem that stunting or growth retardation are comparative terms—stunting in relation to what? At the present time there does not exist an adequate reference for height velocity. In Tanner's original standards (3), the intervals are too long for detailed study of growth velocity during the first 2 years of life, which I believe to be the critical period.

The findings presented in Figs. 1 and 2 are derived from various studies in developing and developed countries. Wherever possible I have chosen longitudinal or semilongitudinal studies. Even when children have been measured longitudinally, the published results usually give only average heights at different ages. Differences between heights at different ages thus represent average increments rather than velocities; they give no information about the standard deviations (SD) or centiles of growth velocity, so that no judgment can be made about the range of so-called normality. Moreover, the process of putting together different sets of figures and making comparisons involves many sources of variability and error. In some studies the sexes are not separated; it is often not possible to be certain about the accuracy of the ages; some of the data are clearly not of good quality; in some Third World countries there may be seasonal effects that were not allowed for; different authors use different age intervals, e.g., 4-week periods, months, decimal years. Social class may vary; some studies are urban, others rural. The numbers of children also vary greatly, both between and within studies. When overall averages have been calculated, no attempt has been made to weight them for numbers. Finally, I make no claim to have taken into account all results that may be available in the literature; there are many studies reported in local journals that are not so easily accessible. Even among the four sets of values from industrialized countries, there are not inconsiderable differences among the average increments.
NATURAL HISTORY OF STUNTING

My aim is simply to take a preliminary look to see whether patterns or trends emerge that are worth a more detailed examination.

When Does Stunting Begin in Third World Children?

The results in Fig. 1 for increments over 3-month periods seem to confirm the suggestion made 10 years ago (2) that linear growth begins to fall off in the second 3 months of life if not earlier. The average increments remain low, at about 80% of reference, until at least the end of the second year, and then there is a suggestion that they pick up.

The young infant is of particular interest. Figure 2 is an attempt to find out whether the deficit starts even before 3 months. The results in this figure are not very satisfactory, since I found only 11 studies with monthly measurements of length, and it is likely that over such short intervals differences are not very accurate. At this age there are also likely to be large variations between ethnic groups in feeding practices, seasonal effects, and so on. By comparison with the industrialized countries, there is some evidence of faltering after the third month but not before that.
FIG. 2. Average monthly increments in length during the first year of life in children from developing (dark bars) and developed (light bars) countries. The bars represent the range of variation between studies. Numbers above the columns indicate the number of studies. Sources of data for developing countries (boys or mixed sexes): Australian aborigines (4), China (5), Eskimos (29), India (13,14), Kenya (17), Nigeria (19), Pakistan (30), Papua–New Guinea (21), Philippines (22), Zaire (23); for developed countries (boys): Australia (see 24), Netherlands (26), UK (31), USA (28,32,33).

Is the Comparison Between Third World and Industrialized Countries Appropriate?

Conclusions drawn about faltering may be criticized on the grounds that the so-called standards of developed countries are inappropriate. The major questions about genetic and environmental influences on growth are discussed elsewhere in this volume by Davies and Martorell et al., but there are two other points that should be taken into account.

The first is the influence of breast feeding. The NCHS reference, its predecessor, the Harvard standards, and possibly both Tanner's standards and the Dutch ones reflect the growth of infants who were probably mainly formula fed, because these were compiled before the recrudescence of breast feeding in industrialized countries. In the words of Whitehead and Paul (34):

It is perhaps not unreasonable . . . to suggest that now infant feeding practices have changed so markedly we might consider the systematic collection of data for the reconstruction of new growth centile charts. Surely we should not just assume that what was happening to the growth of children 20 to 50 years ago, when the majority of children were fed on what we now realize were inappropriately constituted and administered formulae, coupled with the early administration of solids, is the rational anthropometric target to aim for at the present time.
Whitehead and Paul's figures seem to show some falling off in attained length in boys at about 9 months and in girls at about 6 months (34). It is puzzling that most of these infants had been exclusively breast fed for not more than 4 to 6 months, so that the faltering seems to begin and to be maintained after supplements were introduced.

Table 2 shows results of three comparisons in developed countries between formula-fed and exclusively breast-fed infants. The increments between 0 and 3 months were the same with both types of feeding; after 3 months they were consistently less in the exclusively breast-fed babies and close to those of the developing countries shown in Fig. 1. If the average growth curve in those countries is close to that of breast-fed babies, is it fair to use the word "faltering" with its connotation of something undesirable? That is not a question that can be taken up in this chapter, which is concerned with data rather than with interpretations.

A second problem is that in developing countries there is a high proportion of infants with low weight at birth. Could the "bad start" that these children have cause the falling off in average increments during the first year? A great deal of work has been done in developed countries on the growth of premature and small-for-date infants. The impression is that at least the prematures usually show greater than normal incremental growth (e.g., 37).

Table 3 shows comparisons made in India and Guatemala of growth in length of low-birth-weight and normal-birth-weight infants. In this table I have excluded the extremes of low birth weight since we are not concerned here with frankly pathological states. Except in the study of Bhargava et al. (11), most of the low-birth-weight children were probably small for gestational age. There seems, within this range, to be no consistent difference in growth in length related to low birth weight. Therefore, I conclude that the falling off shown in Fig. 1 is not caused by dilution of the samples by infants of low birth weight. However, more evidence on this point is needed.

### TABLE 2. Comparison of increments in length during the first year of life in exclusively breast-fed and formula-fed infants in industrialized countries with average increments in Third World countries*

<table>
<thead>
<tr>
<th>Age interval (months)</th>
<th>Increment (cm)</th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>Formula-fed</td>
<td>Breast-fed</td>
</tr>
<tr>
<td>0–3</td>
<td>9.6</td>
<td>9.5 (3)</td>
</tr>
<tr>
<td>3–6</td>
<td>6.2</td>
<td>5.8 (3)</td>
</tr>
<tr>
<td>6–9</td>
<td>4.6</td>
<td>3.95 (2)</td>
</tr>
<tr>
<td>9–12</td>
<td>4.1</td>
<td>3.6 (1)</td>
</tr>
</tbody>
</table>

*Numbers of studies in parenthesis. Breast- and formula-fed data from Owen et al. (35), Evans (31), Salmenperä et al. (36). Third World data from Fig. 1.
TABLE 3. Increments in length of low-birth-weight and normal-birth-weight infants

<table>
<thead>
<tr>
<th>Age interval (months)</th>
<th>Indiaa Mean birth wt. (kg)</th>
<th>Indiab Birth wt. (kg)</th>
<th>Guatemalae Birth wt. (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.8 ± 0.2</td>
<td>2.0–2.5</td>
<td>2.0</td>
</tr>
<tr>
<td>0–3</td>
<td>9.1</td>
<td>8.7</td>
<td>8.7</td>
</tr>
<tr>
<td>3–6</td>
<td>7.4</td>
<td>6.2</td>
<td>5.4</td>
</tr>
<tr>
<td>6–9</td>
<td>4.8</td>
<td>3.5</td>
<td>3.8</td>
</tr>
<tr>
<td>9–12</td>
<td>3.4</td>
<td>3.4</td>
<td>3.3</td>
</tr>
<tr>
<td>Total, first year</td>
<td>24.7</td>
<td>21.1</td>
<td>21.2</td>
</tr>
<tr>
<td>Length at birth (cm)</td>
<td>44.6</td>
<td>47.9</td>
<td>41.6</td>
</tr>
</tbody>
</table>

*Data of Datta Banik et al. (38) for mixed AGA and SGA infants.
aData of Bhargava et al. (11) for AGA infants.
'eDate of Mata (9) for mixed AGA and SGA infants.

How Long Does It Take to Become “Significantly” Stunted?

The calculations that follow are all in terms of increments, and for this purpose the NCHS reference (27) is used rather than the “mixed” reference of Fig. 1. A child whose increments from month to month are less than those of the NCHS median is described as having an incremental deficit; his increments will be expressed as a percentage of the reference median increments. The calculations also assume, for the sake of simplicity, that a child has the same incremental deficit throughout the first 3 years of life. Obviously this is not true, but one has to start with some simplifying assumptions.

Figure 3 shows the attained length at different ages, expressed as a percentage of NCHS reference median, of children whose average increments were 80%, 65%, and 50% of the reference increments. From Tanner’s velocity data (3), these deficits correspond very roughly to −1, −2, and −3 SD. The figure also shows a line for 90% of NCHS median length, which is commonly taken as a cut-off point for a child to be classified as stunted. It is obvious that the smaller the incremental deficit, the longer it takes for a child to cross the cut-off line. It follows that in a population of children with varying degrees of incremental deficit, the number that cross the line will increase with time. In this model, the prevalence and distribution of stunting remain constant, but the prevalence of stunted children increases. For this reason it seems quite unjustified to draw the conclusion, as some have done, that “chronic malnutrition” is a more serious problem in older than in younger preschool children.

The argument implies that what matters from a physiological point of view is not a deficit in attained length or height but a deficit in rate of growth. If that is correct, it follows that it is unsound to use a cut-off point for attained length that is the same over the whole age range. If we are going to use cut-off points at all, and they are sometimes necessary for public health purposes,
it would be more logical to put the cut-off point at each age as the length representing the result of a given deficit in incremental growth, say, 65% of the reference median increment. This value might be chosen as a cutoff because it corresponds roughly to −2 SD of standard velocity. When we have more data on the SD of increments, we can, if we want to, choose a more appropriate cut-off point. The result of this approach is shown by line B in Fig. 4; this line could be called the “incremental cutoff.” Line A represents the conventional cutoff of 90% of reference median attained length. It is apparent that line B will lead to more children being classified as stunted at younger ages and fewer at older ages. I believe that from the public health point of view this would present a much more realistic picture. It would be very simple to prepare charts of attained length that show this new cut-off line; it would be more difficult to explain how it was derived.

VARIABILITY OF LINEAR GROWTH

It is common to regard growth in length as much less variable than growth in weight. This is probably wrong: it is the measurement that is more difficult. Tanner’s velocity data show a coefficient of variation during the first 3 years of life of about 16% (3). I presume that this represents between-subject variation. Fomon and his colleagues have recently been analyzing their data on the growth of infants
up to about 4 months. Measurements were made at intervals of 2 to 4 weeks. As one might expect, the growth from one period to another is more variable in some children than in others. Fomon should be able to tell us the range between subjects of within-subject variability. This will be very important information.

In Third World countries there are marked seasonal variations of growth in length or height, which can be shown very clearly over periods as short as 2 months. They are documented in this volume by Nabarro et al. and by Tomkins, so I need not discuss them further here except to conclude that the rate of growth in height as well as in weight is quite sensitive to environmental factors.

**CATCH-UP**

The term "catch-up" is somewhat ambiguous. It is obviously necessary to distinguish between catch-up in attained height, so that final height is within normal limits for sex and age, and catch-up in the rate of growth. There is also a problem
in assessing the extent of catch-up in rate, because the observed increment over any period can be compared with the expected increment either in children who start at the same age or in children who start at the same height. Either method seems to have its logic.

The possibility for catch-up in attained height is limited by the maturation of the ossification centers, which seems in general to be less retarded than linear growth (39). There is a large literature on catch-up growth, but much of it is concerned with rather older children than those considered here and with the effects of making good hormonal deficits, e.g., of thyroid and growth hormones, as discussed in this volume by Rappaport. However, if the rate of growth in height is indeed responsive to environmental, including nutritional, factors, one would expect catch-up growth to occur whenever nutritional conditions become favorable. There is impressive evidence that this can indeed happen. As one example, Prader and co-workers (40) have shown remarkable gains in height when treatment is instituted in previously untreated children with celiac disease. These children were, of course, living in a good and clean environment, but the findings illustrate what is physiologically possible in young children.

Further evidence of the rapid responsiveness of linear growth is provided not only by the seasonal changes mentioned above but also by the catch-up that can occur during a relatively short period of treatment of malnourished children in hospital (Golden, this volume).

Table 4 summarizes the results of three long-term studies in which children who had been severely malnourished were reexamined after several years. In the Peruvian study (43), a small group (A) of malnourished children, after discharge from hospital, were brought up in the homes of well-to-do foster parents. These were

### Table 4. Later catch-up growth of children malnourished in infancy

<table>
<thead>
<tr>
<th></th>
<th>Height as percentage of standard (NCHS, boys)</th>
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<tr>
<td></td>
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<tr>
<td><strong>South Africa (41)</strong></td>
<td></td>
</tr>
<tr>
<td>Admission to hospital</td>
<td>86.6 (35)*</td>
</tr>
<tr>
<td>Follow-up, 5 years</td>
<td>87.4 (77)</td>
</tr>
<tr>
<td>Follow-up, 10 years</td>
<td>90.1 (78)</td>
</tr>
<tr>
<td><strong>Jamaica (42)</strong></td>
<td></td>
</tr>
<tr>
<td>Admission to hospital</td>
<td>92.8 (56)</td>
</tr>
<tr>
<td>Follow-up, 2–8 years</td>
<td>101.1 (56)</td>
</tr>
<tr>
<td><strong>Peru (43)</strong></td>
<td></td>
</tr>
<tr>
<td>Admission to hospital</td>
<td>Group A&lt;sup&gt;b&lt;/sup&gt; 86.1 (8)</td>
</tr>
<tr>
<td>Discharge from hospital</td>
<td>91.2 (8)</td>
</tr>
<tr>
<td>Follow-up, 6–10 years</td>
<td>97.9 (8)</td>
</tr>
<tr>
<td>Group B&lt;sup&gt;c&lt;/sup&gt;</td>
<td>86.0 (8)</td>
</tr>
<tr>
<td></td>
<td>90.1 (8)</td>
</tr>
<tr>
<td></td>
<td>89.7 (8)</td>
</tr>
</tbody>
</table>

*Numbers of children in parentheses.
<sup>b</sup>Taken by well-to-do foster parents.
<sup>c</sup>Returned to impoverished homes.
compared with a group (B) of children matched for age and sex who, on discharge from hospital, returned to their own poor families.

One can conclude from the Jamaican study (42) and from the Peruvian group A that even after severe retardation, virtually complete restoration of normal height is possible, at least up to the age of about 10 years. The failure of catch-up shown by the South African children (41) and by the Peruvian group B is presumably the result of continuing deprivation.

The question then arises whether even in these children eventual catch-up would be possible as a result of delayed maturation and prolongation of the pubertal growth spurt. Only one study has gone on long enough to address this question, that of Satyanarayana and co-workers in India (44). They separated 5-year-old children into different groups according to their height and reexamined them at intervals up to the age of 20. The initial deficit of the shortest group was 15.5 cm; they were still 10 cm shorter at 20 years, but between the ages of 5 and 20 the increment was greater in the initially shorter children and equal to that of American boys over the same age interval. Thus, although a serious deficit was established by the age of 5, it did not prevent these children from growing at a normal rate thereafter. But why could they not grow at a faster rate than normal and so catch up in attained height? Was the limiting factor food intake or infection or heavy manual work? Or was growth during this phase of life controlled by genetic factors, small adults producing small children, who in turn became small adults? In the society in which this study was done, there is evidence that smallness may be a disadvantage when it comes to earning capacity, so that perhaps people are particularly poor because they are small rather than the other way around.

These questions provide an introduction to the chapters that follow by Martorell et al. and Davies.

CONCLUSION

In the early years of life, growth in length is very sensitive to nutritional and other environmental influences. In developing countries the growth rate often falls off within a few months of birth but tends to return to normal after the age of 3 years. This leaves the children with a deficit in attained height and body size compared with their better-off peers. Is it acceptable to regard this as an adaptation? (for discussion see refs. 45, 46). If conditions are favorable, young children may achieve remarkable degrees of catch-up in linear growth, so the physiological capacity is preserved but only seldom expressed. We do not know the extent to which short stature in adults in developing countries is determined by deficits in early life. Is it possible that genetic differences in height become established at the time of the pubertal growth spurt?

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**DISCUSSION**

*Dr. Davies:* You referred, Dr. Waterlow, to the faster growth of bottle-fed versus breast-fed babies. One of the problems in making these comparisons is that we are often comparing one population with another, and often at a different time. What we need to do is to compare breast- and bottle-fed babies within the same time period. If this were done we would obtain a far more accurate comparison between bottle-fed and breast-fed babies. We are currently studying the growth of South Chinese babies born in Hong Kong and in Canton using similar methodology. These babies share a similar population genotype. Hong Kong is now largely a bottle-fed population; very few are breast fed. In South China most babies are still breast fed. Yet the pattern of linear growth and weight gain over the first 6 months of life is almost identical in Hong Kong and Canton.

*Dr. Barbara Golden:* I suggest that ethnicity may affect length more than weight for length, and therefore the standards may be more variable between communities. Thai community standards, for example, will be more different from the NCHS standards than the Jamaican ones.

*Dr. Guesry:* Is it true that static measurements of final height will depend much more on ethnicity than velocity measurements?

*Dr. Van Lerberghe:* I do not have any concrete evidence on that, but it seems to me that errors of age and errors arising from ethnic differences, which are so important in the analysis of static measurements (attained length), probably become much less important when
we analyze velocity measurements, certainly as far as their implication and clinical significance are concerned.

**Dr. Waterlow:** The question of ethnic differences will be fully covered in the chapters by Drs. Davies and Martorell et al., so I think that we could leave that for the moment.

**Dr. Martorell:** Yes, we will indeed be focusing on ethnic differences in growth. It should be underscored that most of us are interested in this issue because we use growth data to assess nutritional status. We would like to evaluate children using appropriate reference data. It is also important that we concentrate, where possible, on longitudinal data and not on attained status. Growth monitoring in young children is a useful tool for selecting children at risk of poor health. A key question is whether the functional implications of growth retardation vary by age. I believe this is the case and that the earlier the retardation, the more likely that it will be associated with poor nutritional outcomes.

**Dr. Guesry:** I would like to return to the question of the faster growth of formula-fed compared with exclusively breast-fed babies. I am prepared to accept that the faster weight gain may be considered deleterious, although adult obesity does not seem to be related to infant obesity. However, I can hardly imagine how faster growth in length could be deleterious.

**Dr. Waterlow:** I do not know whether it may be deleterious. I was simply trying to present facts. For example, in Owen's study (1) in the United States, the gain in length of exclusively breast-fed infants in the first 3 months of life was 98% of the reference, and in the second 3 months it was 88% of the reference. The NCHS reference is, of course, based largely on data from formula-fed infants.

**Dr. Guesry:** It has been said that excessive protein intake early in life could induce excessive insulin release, which could be responsible for faster growth, at least in length, and later on could induce diabetes. Dr. Rappaport, could you comment on this?

**Dr. Rappaport:** I have no specific comment on insulin. A high protein intake will also stimulate the production of growth factors.

**Dr. Milner:** This workshop is concerned with stunting in the Third World, and later we shall be considering whether a low food intake can produce a deficiency of growth factors. In Western countries, when growth hormone deficiency has been diagnosed, it takes several years' treatment to produce catch-up in height.

**Dr. Waterlow:** I wonder whether clinical data of this kind in older children are relevant to our problem.

**Dr. Nabarro:** Our main concern is with the growth of children in developing countries. We need to be careful when applying the results of clinical experience in Western countries. However, this experience may help us to identify the questions to be solved. We should not apply the experiences from one environment to another without the necessary supporting data.

**Dr. Rappaport:** I agree that the growth hormone model may not be the most appropriate model in the present context. We discuss this in later chapters. I hope also that during this meeting we will be able to elaborate more on the question of catch-up growth. In this connection I would like to return to the earlier discussion on breast feeding and growth. Dr. Waterlow, did you not say that between 1 and 2 years of age, infants have the same pattern of growth whether they have been breast fed or artificially fed? That would imply that there is catch-up growth during the second semester of life.

**Dr. Waterlow:** I did not mean to imply anything so positive. The studies that I am familiar with, comparing breast-fed and formula-fed babies, have usually not gone on long enough to answer the question. If Dr. Davies' study will continue into the second year, it should be possible to answer Professor Rappaport's question.
Dr. Davies: The intention is to continue the study for 5 years.

Dr. Milner: As a clinician I have serious reservations about whether measuring length in the first to second year of life is practical.

Dr. Aponso: As regards the feasibility of linear growth measurements in infancy: yes, these measurements can be carried out for any specific research project. For instance, we are currently conducting a research project on linear growth in babies and preschool children in collaboration with the London Institute of Child Health. It would, however, be almost impossible for a busy practicing physician to look at linear growth as a measure of growth and development in infancy. In fact, what is the importance of linear growth during the first 6 months of life in Third World countries? Is it all that important?

Dr. Waterlow: I am not proposing that these measurements be done by busy clinicians. I am thinking of research, surveys, and child welfare clinics. Admittedly, it takes three people to measure the length of a young child accurately, but if it does turn out that these measurements are important for public health, not just for clinical pediatrics, then we should try to make them.

Dr. Guesry: An additional problem is that when assessing "faltering" in linear growth, we need to know the exact age of the infant, which is not the case when we assess wasting, because then we relate body weight to height.

Dr. Milner: Age is indeed critical for the assessment of growth retardation, because the "normal" velocity is much higher from 3 to 9 months, for example, than from 15 to 21 months.

Dr. Waterlow: Indeed, a small difference in age will have a very big effect in the first 6 months. That is why we need velocity standards covering shorter intervals than the 3-month intervals of Tanner's standards. I hope that this Workshop will conclude that monthly increments in length are important. I should also like to stress again the variability of monthly increments. This is another subject on which we need more information.

Dr. Golden: Length measures the growth of the whole skeleton. Do we need something more?

Dr. Waterlow: I know that there are ethnic differences in the relative lengths of different parts of the skeleton, e.g., trunk and limbs (2). I do not know whether these differences exist in infants and, if they do, whether they are large enough to interfere with using linear growth to assess nutritional state.

Dr. Davies: It is also a mistake to presume that all babies keep within the same centile channel in the early months after birth. This is a period of very considerable growth shift, both upward and downward. In individual infants this sometimes makes the interpretation of an apparent faltering difficult. In some instances, and this obviously applies far more to children in the developed world, apparent faltering could well be physiological.

Dr. Tomkins: The attained weights and heights of children in relation to the reference may vary considerably in different periods of the year. A child's length may be satisfactory at one moment but may not be so 3 months later. This makes the interpretation of longitudinal data very difficult.

Dr. Waterlow: I accept Dr. Davies' point that it is unrealistic to suppose that a child will grow along the same channel for 2 or 3 years. I agree with Dr. Tomkins that, as he, Dr. Nabarro, and others have shown, linear growth, as well as weight gain, is quite sensitive to environmental influences. Unfortunately, it is difficult to make use of this sensitivity because of the variability in the rate of linear growth even in "normal" children. One of the problems in the data that I had access to was that they told us nothing about the variability among different children. As I have said, we need much more information on this before we can plan how to make the best use of data on length velocity.
Dr. Kraisid: Does one observe differences in growth velocity between infants receiving milk-based and non-milk-based supplementary food? When milk-based supplementary foods such as cow's milk are given, growth velocity may not falter as it does in children receiving non-milk-based supplements.

Dr. Waterlow: I cannot answer that question. The data that I presented are derived from over 20 studies conducted in various countries. Most of them say little about the feeding pattern, so I doubt if it will be possible to answer your question. However, I would draw your attention to a study by Fomon and co-workers (3) in which they showed that babies fed on a skim-milk mixture, which is high in protein but low in energy, grew as well in height but less well in weight as children on a normal formula.

Dr. Ousa: We have had the opportunity to study the growth pattern of children from low socioeconomic classes and with a background of poor sanitation. The growth velocity of children with low birth weight is quite good when they are breast fed because the amount of breast milk may be adequate for these small babies. However, in those with high birth weight, the growth velocity fell off sooner. We have difficulty in analyzing the weight-for-length data of our children under 1 year because they are much below the growth pattern of the developed countries. I think that the international standards may not be appropriate and that a local reference should be used.

A related question is whether the duration of pregnancy and of intrauterine growth retardation have any influence on subsequent stunting.

Dr. Waterlow: With regard to your first point, I am glad to hear what you say. I mentioned in my chapter evidence for catch-up by low-birth-weight babies (provided that they survive); I tried to argue that because of this catch-up, dilution of the sample by large numbers of low-birth-weight babies could not account for the apparent falling off in growth rate after the first 3 months of life. I think that your second point, the applicability of an international reference, would be best discussed after Dr. Keller's chapter.

Dr. Martorell: We need to distinguish between the two types of low-birth-weight infants: those with low weight for length at birth and those with adequate weight for length. In an investigation carried out in 200 Guatemalan children, we found that postnatal growth and development patterns were very different for these two groups (4). Low-birth-weight infants with low weight for length experienced catch-up growth in weight during the first few months because of increased fat deposition. Overall, the low-birth-weight infants with adequate weight for length remained lighter and shorter and had smaller head circumferences at 3 years of age. These infants also performed poorly on developmental tests. These effects, we believe, reflect differences in the timing and duration of the nutritional insult. Our hypothesis is that newborns with low weight for length are affected late in pregnancy, whereas infants who are small but symmetrical (i.e., adequate weight for length) are affected earlier in pregnancy and for a longer period of time. One might consider these situations to be equivalent to acute and chronic intrauterine growth retardation, respectively.

Dr. Guesry: Dr. Martorell, is it also related to prematurity and intrauterine growth retardation?

Dr. Martorell: Prematurity is a very important determinant of postnatal growth and development. However, I neglected to say that in the study I just cited, we considered only term low-birth-weight infants.

Dr. Valyasevi: I hope that one result of this Workshop will be to provide indicators of when preventive measures are necessary.

Dr. Waterlow: That raises the key question that we have not yet tackled. If we accept that deficits in linear growth do occur, what is their significance?

Dr. Guesry: How long does a child need to be stunting before he becomes stunted?
Dr. Golden: Referring to Fig. 4 of the chapter, the time that it takes to cross line B has to be taken into consideration.

Dr. Waterlow: Yes, indeed. The question is: How much does it matter to have been subjected to a process of linear growth deficit (stunting) for 3 years compared to 6 months. If we want to use cut-off points, which are sometimes useful for public health purposes, line B would represent the continuation of a process and might be a more physiological cutoff than the conventional line A.

Dr. Guesry: Could one of the practical conclusions from this session be a suggestion to modify the way of assessing stunting, thus leading to intervention, as requested by Professor Aree Valyasevi earlier. Has anyone a comment on the practicability of changing the cut-off points for the assessment of stunting?

Dr. Nabarro: I think that we should, at this stage, make recommendations on how the length growth of individual children should be charted and what should be considered the desirable rate of length increment. In the 3 days of this Workshop, we have to answer some basic questions first and then think about practical implications later. The important questions to be asked are (a) What is happening? and (b) Does it matter?

Dr. Waterlow: We may have some idea about the first question, but we have virtually none about the second. What are the physiological implications of growing at two-thirds of the normal velocity for the first 6 months of life compared to the second year of life? Or suppose a child grows at 65% of the standard rate for 6 months and then gets better, whereas another child grows at 80% of the standard rate for 2 years. I would like to know whether they will be in the same physiological state when they are at the same point for attained height.

Dr. Milner: The one who suffered growth retardation longer will be more disadvantaged.

Dr. Waterlow: Even if the retardation is mild? I wonder. The effect may depend not only on the degree of deficit and how rapidly it is established but also on when it occurs, according to Dobbing's concept of vulnerable periods.

I hope that other chapters may throw more light on these questions. The objective of this session was to raise them.

REFERENCES