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SIXTY-THIRD SCIENTIFIC MEETING—TWENTY-NINTH SCOTTISH MEETING

USHER INSTITUTE, EDINBURGH

14 OCTOBER 1950

GROWTH

Chairman: PROFESSOR F. A. E. CREW, F.R.S., *Usher Institute of Public Health, Edinburgh*

Growth and Health

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A general introduction to a discussion on growth and health might take either of two main forms. It might review what we know about the material requirements for growth: the total energy needs, the grams of protein required to give this or that amount of soft tissue growth, the grams of calcium and phosphorus required for growth of the skeleton; it might discuss the functional importance of substances that make little material contribution to growth, and finally, sum up what we know about the interrelation of diet and resistance to infection. These are the subjects with the details of which most of the observational and experimental work in nutrition is, at the moment, concerned. It would take days to sum up the information; and, when that had been done, I doubt whether we should be able to do more than reaffirm general principles. These general principles are already well known. The concept of a balanced diet has become part of our 'common knowledge'.

Perhaps partly because I shirked that major task, and partly because I think it is good, now and then, to lay aside the microscope and look at things with the naked eye, I have chosen the second approach. In very general terms I am going to ask what we mean by good growth and by health and what the one has to do with the other.

In experimental work with animals most often weight increase is taken as if it were synonymous with growth; less often growth is defined as increase in one or more linear dimensions. Obviously increase in weight may be increase in bone or muscle or fat or merely water or some combination of any or all of these; and some linear dimensions may be just as difficult to interpret. But suppose we had some complicated technique combining weights and measures and isotope studies and specific gravity of the body, what would it tell us about growth? It would be no more than a means to a crude chemical analysis without killing the subject, and, by itself, it would be just as interesting or as sterile as any other chemical analysis.

Before we can get up any real interest in the result we must know what changes in the structure and composition of the body mean in terms of some standard of value. What is value in growth? Why do we say this animal or person is well grown and that is not? We mean a great deal more, I think, than merely that the one is bigger or heavier than the other. The term well grown and the attitude of mind behind it imply some target of performance which we consider to have been approximated or missed.

Nature and nurture

In an attempt to clarify that idea, I have built up an argument in picture form. In the first place we must go back to the basis of growth, which depends on nature and nurture, but we should not require either complex genetical concepts or the refinements of chemistry to make the argument plain.

The fundamentals of genetics, or all of them that need concern us here, have been known for thousands of years; they are part of everyday language, everywhere. 'Like begets like'; 'like father, like son'; 'what is bred in the bone...'; 'you cannot make a silk purse out of a sow's ear': these and similar clichés exist in all languages, sometimes in quaint forms, but with the same meaning. Even primitive man must have recognized the sometimes astonishing resemblance of child to parent, and even so-called primitive races of mankind have long practised systematic selection and breeding of their domestic stock. It is equally true that there has long been an awareness of merit in human reproduction. The ancient Greeks, and even earlier civilizations, had clear views on eugenics; and the same awareness, the same urge to 'good breeding' certainly persists in full force, and sometimes in strange forms, at the present day. I do not know whether, or to what extent, Plato's plans for human stud farms materialized, but modern and better informed people accept similar ideas.

We have no galaxy of clichés about nurture, which is not difficult to understand. It is still impossible to disentangle the effects of different components of the environment, especially in human populations where they can seldom be varied or controlled independently, and where cause and effect are so liable to be confused. For instance, tailors were, at one time, perhaps still are, accepted as of poor physique. But that is not because tailoring interferes with growth that is, in any case, already past, but because the relatively unfit gravitate to occupations that require relatively little physical strength. But better and worse diets were certainly distinguished and are, to some extent, embodied in racial beliefs of one kind and another. Perhaps the attribution of the peculiar virtues of the English to the eating of roast beef may enjoy a scientific rebirth with the ascent of the 'animal protein factor' to its present prominence in experimental work.

The effect of nurture on the concrete and visible expression of nature has, in the past, received too little attention at the hands of geneticists and plant and animal breeders. Let us review briefly what nurture can do to inhibit the expression of nature and what the significance of that inhibition may be.

In plants. Baur (1911) has described two dandelion plants, one grown high in the Alps on poor soil and in the cold, the other in the warm and fertile plain. If the dandelion were an important food plant, the verdict would be that the big, succulent plant is the better. But consider a different plant. Exactly the same occurs if edelweiss is transported to a warm and fertile garden. It loses its grey colour and white hairs; it stretches out and becomes green and leafy, the flower looks different; in fact an uninteresting plant. The Alpine is the plant that is prized. This little story has two morals. The first is that if one has seen a plant, or animal, only in one environment, all one knows about its genetic constitution is what it can do in that environment and not what it may do or not do in any other. The second is that the terms good and bad, better and worse, as descriptions of plants of animals, are not absolutes, but are valid only in relation to environment, and that they imply some criterion of value which may be utilitarian or aesthetic or both. This is now, of course, well recognized in relation to crop production. For instance, a very large chapter in the history of Canadian agriculture is the story of the search for varieties of wheat that would survive the dry, cold climate of the prairies, that would grow and ripen in the short growing season, and that would resist indigenous diseases.

In animals. This is not yet so well realized in regard to animals, so let us look at what the wrong nurture can do to animal nature.

McMeekan's (1940*a–c*, 1941) papers on the growth of pigs show (Pl. 1, Fig. 1) how a well-bred or 'improved' pig grows. One can see the change in shape as the animal grows from birth to the approved 200 lb. bacon pig. In shape, the original wild pig at the fully grown stage is much more like the improved pig at birth than at maturity. The important thing is that the characteristics that are valued by the pig farmer, who is going to sell pork or bacon, are those which develop last. The most prized parts of the pig are the loin and hind-quarters. And the quality of the joints depends on the distribution of lean and fat. The same is, of course, true of beef and mutton.

A series of most important experiments, started in Dr Hammond's laboratory in Cambridge and continued in New Zealand, was made to test the effect of feeding on the development of the carcass of pigs and lambs. They showed in the most striking fashion that poor feeding not only stunts, but also delays indefinitely and, if continued long enough, permanently prevents, the full development of the later-developing and best parts of the carcass. If a bacon pig is underfed for half its short life and then given a full ration, this 'low-high' pig will certainly put on weight. But the important point is that the skeleton and muscle will not grow as they would have done if they had had the opportunity at the right time, and the extra food will be used mainly to lay on fat (McMeekan, 1940*c*, Pl. 27).

Growth potential

The moral of this is that growth potential is not a thing that one can speed up and slow down, as one can accelerate or retard a chemical process, and get the same result in the end. If one does not use the full potential all the way along one does not get full development. One may get the same ultimate weight but one will get a carcass that is different in shape and in composition. Now we have an idea of what is implied by a well-grown pig. If it is also fat, that should be 'finish' added when the correct framework of bone and muscle has grown to the desired size.

It may seem that it is a long step from bacon pigs and prime beef or mutton to man. Not so long a step perhaps.

An old diagram, drawn by Stratz and widely reproduced, e.g. by Brody (1945), of the change in shape that occurs in man during growth shows that, in essentials, the change is the same as in the pig. Development is from the cephalo-thoracic region forwards and backwards and the hind-quarters mature last. If the rate of growth is sufficiently slowed the adult is not only small but underdeveloped, with normal or nearly normal size head, moderately retarded trunk and relatively short legs.

Let me make quite clear at this stage that this does not necessarily mean that all small adults are underdeveloped. There are still all too many whose small total height is attributable to rickets in infancy. Often they are people with a high growth potential whose parents were quite simply ignorant of any special need for material for calcification of bone. But, apart from these, and possibly differences of build due to variations in endocrine balance, it would be expected on general principles that children continuously underfed would grow into underdeveloped adults. If this is so, a difference in body proportions should be demonstrable in association with differences in height wherever persistent differences in nurture are known to exist. And that, I submit, can even now be confirmed by observation in any city in this country, if one looks for it.

Proportionate growth of children

The graph depicting social gradient in height of schoolchildren between 1927 and 1935 which is to be found in *Food, Health and Income* (Orr, 1937) does not represent the extreme difference at that time. Selection of data for poor urban council schools gave a curve that was still lower. I tried to find recorded data to test my hypothesis about difference in shape, but unfortunately leg length is a measure not often recorded. At that time I found only one set of data (Hansen, 1932) from which similar conclusions had been drawn and which quoted, from an earlier observer, that 'Full typical development in man implies, relatively to body length, short torso, long arms and long legs.' It is a set of measurements of Copenhagen schoolchildren, which included not leg length but sitting height, and deduced that taller children had relatively longer legs and were relatively heavier. (The difference would probably have been more obvious if leg length had been measured.) Anyway, when the Carnegie U.K. Dietary and Clinical Survey was planned at the Rowett Research Institute in 1937, cristal height*, as a measure of leg length, was included in the measurements to be made. Statistical analysis of the data, divided into groups according to expenditure on food, has only recently been completed and the gist of the results is as follows. I am indebted to Mr Quenouille of the Statistical Department, University of Aberdeen, for the information.

The three measurements, height, cristal height and weight were analysed to find out

* Height from the floor to the highest point of the iliac crest.

which predicted most reliably the expenditure group to which a child belonged. It was found that cristal height was consistently better than total height for indicating expenditure group and, for age groups under 12, height was better than weight. In other words, the difference in leg length was relatively greater than that in either total height or weight.

That is to say, this idea was statistically confirmed as far as social gradient is concerned; and confirmed at a time when that gradient was already rapidly diminishing. But I shall not transgress into Dr Weir's field and talk of secular changes in growth at this stage. Instead, I am going to suggest that the consciousness of this difference is universal and so fundamental that it colours both our literature and our art. In romantic literature, the hero and heroine are always long limbed. If the heroine is small, and of course some readers like her that way, it is always expressly stated that she is 'perfectly proportioned'. Conversely, if the villain has to be large, he is also coarse, brutish or gorilla-like. The same is true in art. One will admit I suppose that advertisements, because they aim to use the most popular imagery, might be a good mirror of popular taste. High-class fashion journals depict women with an extreme length of limb, and decorative art does the same for both men and women. One may think some of the drawings absurdly elongated. Yet, compared with photographs of ballet dancers and mannequins there is, in fact, no great difference in proportions. A very small increase in the ratio of leg length to total height has a surprising effect on appearance. Conversely, a proposition may be proved also by the Euclidean device of *reductio ad absurdum*. When the artist wishes to depict the lower orders, as such, or the comic, he draws people with exaggeratedly short legs and makes them fat, with results which suggest the 'low-high' pig.

Growth target

All this, to my mind, implies that there is a general awareness of a growth target which is physiologically sound because it means full development. And, quite unconsciously no doubt, because the later-developing parts, the legs, suffer most in underdevelopment, their elongation and perfection of shape become the symbol of perfect growth.

The next question is whether this symbolism is purely aesthetic (with a possible tinge of snobbishness) or whether it has some other connotation. And that brings us to health.

What is meant by fitness

It would of course be absurd to suggest that all tall people are necessarily healthy or that all small people are sickly. It might be, and indeed it is, argued that there is no tougher adult than the undersized survivor from the slums of some of our cities. But that is an argument that cuts both ways. If they have survived the tempest of the slums because they are specially tough, then it seems a pity that so many of the breed die young and that they are not beautiful as well as tough when they do grow up. If I argue on these lines I am given one of two answers. The first is that, of course, they are the product of 'natural selection' and therefore obviously superior, the doctrine of the 'survival of the fittest'. The greatest disservice, perhaps, that scientists ever did for mankind was to produce this association of ideas between natural selection and improvement. The entirely false analogy it suggests with such metaphors as winnowing chaff from grain; the altogether false idea that 'the survival of the fittest' implies some absolute virtue and not merely fitness to survive in a given environment, whatever it may be, have done much to hamper and nothing to promote either agriculture or human progress. Progress in any branch of science means increasing control over nature; this is true everywhere from the tilling of the soil to the splitting of the atom: to be content to abandon a large section of the population to the mercy of a man-created, evil environment is so unscientific as, fortunately, to have something quite unreal about it.

The second answer I get is that size has no virtue in itself and that what we want is 'strength'. It is difficult to pin this school of thought down to an exact definition of strength. If they mean 'brute' strength in the general sense of ability to toss cabers and lift heavy weights, or similar muscular performances, that, I should think, is of minor, and rapidly diminishing, social significance, and, in any case strength in that sense is so closely dependent on training that it is hardly worth arguing about. I am reminded of an early attempt to assess physical fitness by measuring vital capacity. The list of persons examined, in descending order of merit, began with boy scouts and ended with beggars and gentlemen.

The idea in the minds of some, at least, of these objectors appears to be that the tall child is something of a 'hot-house plant', a false and dangerous analogy. Obviously if one turns hot-house plants straight out into a cold and unsheltered garden, they will suffer more than plants reared in the open garden, if they can be so reared. But that does not mean that they are inferior or less desirable plants. It simply means that the hot-house is a more desirable environment, for a particular purpose, than the garden. We come back, full circle, to the dandelion and the edelweiss. It all depends on whether we prefer them well grown or stunted and picturesque, if they are picturesque when stunted.

Development in relation to health

Before we leave this question of 'strength', it is perhaps worth while to ask whether height, *per se*, is of any disadvantage in muscular work. An athletic friend of mine thinks it is in football and another suggests that a high proportion of well-known light-weight boxers have come from Glasgow. It would be of great interest to have statistics of the heights and weights of distinguished athletes. So far, I have been able to find only one study, a very recent one (Tappen, 1950) of the world's champion weight-lifters and their records. There are three lifts: the two-arm military press, the two-arm snatch, and the two-arm clean and jerk. The order of weight lifted in the first two is on the average about one and a half times body-weight, and in the third about five times body-weight. In all, the performance is closely correlated with body-weight: coefficients 0·85, 0·82 and 0·80. Since weight and height are themselves correlated, efficiency increases also with height. When weight is held constant, the press lift is hampered by height, slightly but significantly; in the snatch, height has a slight but not significant advantage; in the clean and jerk; the most complicated performance, height has a significant favourable effect on performance. Hence, as far as this goes, height is a slight handicap where the stance is rigid, and the performance relatively slow, but where speed and agility are required in addition to muscle strength, then height is positively correlated with lift.

So much for feats of muscular strength. Where 'strength' involves also endurance there is indirect evidence that height, weight and performance are correlated. For instance, the lower limit for admission of regular recruits to the navy has been consistently higher than that for the army; and that for the air force (flying personnel) was, at least to begin with, still higher. That meant, of course, that these services were recruited from progressively higher strata of society. Further, within these services, rates of sickness and invaliding decreased as height and weight rose. Put the other way round, rejects, including those who passed the height test and were rejected on medical examination, were, on the average, smaller than those accepted; and, in times of depression, when the supply of labour exceeds the demand, the same is true.

Development in relation to resistance to infection

We have then, so far, no evidence against the view that better development implies greater physical fitness. What other criteria, in the present state of knowledge, can be applied? Morbidity data are few for the general population and it is difficult to disentangle the causes of sickness. Since all the social circumstances, housing, sanitation, spacing of population and hence exposure to infection, as well as education and, on the whole, facilities for prompt medical attention, improve with, and at about the same rate as, growth, it is difficult to judge whether inhibition of growth itself has any effect on morbidity. Examples could, I think, be cited from animal experiments but I prefer to draw such deductions as may be from human populations. Evidence is afforded by the wartime history of tuberculosis. In both world wars, where diet deteriorated to the extent of inhibiting the growth of children, the incidence of tuberculosis rose in proportion. Such an increase might be attributed to simultaneous deterioration in housing, hygiene, isolation and hospital treatment, such as did occur. If we take the two wars separately the deterioration of the environment by destruction of houses, overcrowding, blackout, and failure of isolation were incomparably greater in the second than in the first, but the effect on tuberculosis, especially in Germany, was much less. Not only was the actual rise less, but the transition from the benign and chronic to the virulent miliary disease (which destroyed the immunological theory of racial immunity), did not occur in the general population, but was seen only among starving refugees and displaced persons. It looks as if underfeeding, which produces underdeveloped people, also interferes with the processes which determine immunity or susceptibility to tuberculosis.

The study of this subject is greatly hampered by the impossibility of recording accurately both attack rate and mortality rate; and even when we have both, we so often do not have age incidence, and that may have a decisive effect on mortality. For instance, infective hepatitis, during the last war, occurred five times as often in British as in Indian troops, but case mortality in Indians was five times that in British troops. Mortality rates were therefore similar (Witts, 1947*a*, *b*) and, if only mortality rate and not also case mortality were known, it might be concluded that there was no difference between the two populations at risk. But the attack rate was probably governed by previous exposure and acquired immunity; the case mortality by the health, probably the nutritional state, of the men. It appears likely that similar sequences of events account for much excess mortality in poor children early exposed to acute infection, and apparent toughness of the survivors in later life.

Let us look at another indication, namely morbidity rate for bronchitis, concerning the same children in the Carnegie U.K. Dietary Survey on whom the physical measurements were made (Table 1). We find the longer-legged children suffered less bronchitis than the short at all ages. Since there is neither complicating immunity mechanism nor specific cure for bronchitis, we might argue that the constitution built up when the complete harmonious pattern of growth is unfolded is, in some way, superior to that associated with inhibition of growth, however slight.

Table 1. *Percentage incidence of bronchitis*

(Unpublished data of the Carnegie U.K. Clinical and Dietary Survey, 1937–9)

	Weekly food expenditure per head of family			
Age (years)	Up to 5s.	5s. to 7s.	7s. to 9s.	9s. or over
		Boys		
0–4	20·5	15·4	10·3	4·3
5–9	10·6	11·4	15·0	6·4
10 and over	5·0	4·0	3·2	2·1
		Girls		
0–4	17·1	11·1	7·1	—
5–9	8·4	6·7	3·4	4·3
10 and over	4·1	2·8	1·4	1·5

The trend of evidence then is that the better-fed and therefore better-developed children and adults are 'fitter', measuring fitness by muscular strength, and 'healthier', measuring health by absence of morbidity where we can get a picture in which the complications can be at least partly resolved.

We cannot go much further in this analysis at present. It would be of the greatest interest to be able to trace accurately the further history of well- and ill-grown people in terms of living and dying and causes of death. I can sum up the general picture (Table 2), in terms of social class, which connotes a general difference in standard of perfected growth.

Table 2. *Mean age at death of males who have completed* 16 *years of life*

(Computed from mortality rates, Registrar-General, 1938)

Social class ...	1	2	3	4	5	All
Mean age at death (years) ...	65·3	65·6	60·4	60·9	60·3	61·4

This shows that, for those who have avoided death in childhood, there is a difference of 5 years in mean age at death between the highest and lowest social classes. An analysis of the reasons, in terms of certified causes of death, is not strictly relevant to this discussion, and I will conclude the argument with one further point. The 'low-high' pig, first stunted in growth and, when it is then well fed, becoming obese rather than 'finished' will be remembered. This, I think, has its parallel among human populations, where privation increases with size of family and some degree of comfort is attained only after growth has ceased. It is, of course, most obvious where adult occupation is not strenuous. That is one form of obesity. The other is that of the well-fed, well-grown person who is vigorous and athletic in youth and then sits back into the physical inactivity of an office and the comfort of a motor car, but continues to eat about as much as he did when young and active. Table 3 (Keys, 1949) shows the cost of obesity in terms of the weighting of life insurance premiums.

Table 3. *The cost of obesity* (*America*)

(Life insurance premiums weighting)

	Premium				
Height (in.)	100 Weight (lb.)	115 Weight (lb.)	129 Weight (lb.)	141 Weight (lb.)	154 Weight (lb.)
60	90–169	170–180	181–195	196–209	210–220
64	98–180	181–194	195–206	207–223	224–236
68	110–198	199–214	215–227	228–245	246–259
72	126–219	220–236	237–252	253–268	269–284
76	142–246	247–263	264–283	284–298	299–314

The moral is not quite the same for both groups. The obesity of the well-grown can no doubt be debited to gluttony and sloth, but I doubt whether that of the ill-grown can be prevented except by the continuation of a spartan regime throughout life, which seems a bit hard. The real answer is good feeding in youth, disciplined eating and habits in later life.

SUMMARY

To sum up briefly: we have seen that there is a physiological basis for preferring tall and long-legged people because, in general, that type represents completion of growth and appears to connote a certain superiority of constitution. I have suggested that there is an awareness of merit in this type which is reflected in literature and art. It is reflected also in the utilitarian sphere of selection for employment. This is rational up to a point, but even where robustness and muscular strength are of little or no immediate importance, there is still a tendency to discriminate against the short, and still more against the generally small person unless he is exceptionally gifted. If one is heavy, one may get by on the basis of being a 'solid' man, but that may have its penalties too.

This discrimination may obviously be of considerable social importance and it would be interesting to have an analysis of mental ability, or of socially valuable performance, in relation to attained physical growth.

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Phases of Postnatal Growth

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The development of the human young from birth to maturity can be divided arbitrarily into a series of stages each characterized by peculiarities of physiology, nutritional requirements, physical proportions, and social adaptation. Whilst it may be convenient to refer to these phases in terms of chronological age, there is a considerable physiological variation between individual children and between the two sexes in the age at which each successive stage is reached and passed. These individual differences become more obvious clinically in the later age groups, but substantial developmental differences in osseous development can be demonstrated radiologically even amongst groups of normal infants and pre-school children of the same age. Mean standards of bone age or osseous development have been established by Todd (1937) and Greulich & Pyle (1950) for children of both sexes from birth to the age of 18 years and are valuable in assessing the developmental age of a particular child.

Methods of assessment

It is the purpose of the present communication to outline briefly the phases of postnatal growth which may be recognized, and to show that these do not bear a consistent relationship to chronological age. Whilst it is not intended to discuss in detail the various methods that have been adopted to assess and analyse growth, it will be realized that our present knowledge has been built up in two ways, the 'cross-sectional' study of large numbers in each age group, and the 'longitudinal' or continued study of the same individuals over a period of years. The methods used in assessing the individual child have evolved from the crude comparison of individual height and weight with mean values obtained from the examination of large numbers of healthy children in each age group. A significant advance was made by the construction of weight-height-age tables for pre-school children (Woodbury, 1921) and schoolchildren (Baldwin & Wood, 1923) in which the necessity for correlating height with weight was clearly recognized. Subsequently height and weight indices (Sutcliffe & Canham, 1950) and percentile ratings have been employed with the purpose of indicating the child's relationship to the mean and to the normal range in each age group, and it has been found that the child tends to retain his position within the group in relation to any particular measurement during childhood (Meredith, 1937*a*, *b*). At the present time, the most satisfactory method of recording individual growth in childhood is probably the Wetzel grid (Wetzel, 1943). From this graphic record in which height and weight