CHAPTER II

SALIENT FEATURES OF THE PROCESS OF PHYSICAL GROWTH AND DEVELOPMENT DURING INFANCY

Introduction :

"All the skills, aptitudes, and emotions of the growing child are rooted in or conditioned by his bodily structure."

J.M.Tanner[1] in the above statement, points out the very fundamental nature of the physical being of the human young. Dr.Tanner has been working in the field of physical growth and development for the last two decades or more. His work has been encompassing the total field of physical growth. He has concerned himself not only with testing beliefs related to physical growth, finding new facts about it, but also with experimentation of new methods of approach to old problems of reporting of growth data and norms for practical use.

In the following pages an attempt has been made to put forth some of his views that are fundamental in nature

---

1. Tanner, J.M.1970 in Mussen, Paul H.(Ed). Carmichael's manual of child psychology. 3rd Edition Vol.I. John Wiley and Sons Inc., N.Y.London, Sydney, Toranto, Chapter 3, Physical Growth, p.77.

as far as physical growth is concerned and are of vital interest to us in this country to clarify our notions about research in the field of physical growth.

If growth is a form of motion, as Tanner (1970) expresses it, than the stage reached at each age is the distance travelled. By the same token the successive increments at each age express the rate of growth or velocity. Of the two, the rate of growth naturally reflects the child's state at any particular time better than does the distance travelled, which depends largely on how much the child has grown upto that point.

Growth in general is a very regular process. It does not proceed by fits and starts, nor does growth in height alternate with growth in transverse or anterior - posterior direction.

According to Tanner (1970), there is not much evidence to support discrete stages in the process of growth and development. In physical growth especially there is continuity. For e.g. the ability to walk and other mile stones are really not discrete stages but visible end results of a process which has been quietly going on. Here also, eventhough the anatomical, physiological and behavioral development tend to occure

simultaneously this simultaneous timing is relative. Skeletal age and dental age do not adhere to this time schedule, and there is certainly not much correlation in the spurt in physical growth and intellectual capacity.

In the words of Tanner 1970, "The process is one of continuous unfolding and movement, with speeds varying from time to time in different parts of the mosaic; it is not a series of keleidoscopic bumps. Only in certain restricted areas do rapid reassortments of the pieces occur, as they fall into new and increasingly precise patterns." *

Tanner(1970) further states that there is no evidence for 'stages' of growth in height (or any other physical measurement) except for the spurt associated with adolescence. Perhaps increment of growth at cellular level are discontinuous but at the level of bodily measurements, even in single bones measured by X-rays, we can only discern complete continuity, with a velocity that changes gradually from one age to another."

In other words, growth of the human young is a very regular and well organised process. As mentioned earlier this process is also self stabilising. Tanner calls it

---

* Tanner J.M. 1970 op.cit. p.133.

"target-seeking". He compares the children to rockets who have their tragectories controlled by their genes and fired by their natural environment. The endocrine glands in their role of chief agents for translating the instructions of the genes into the reality of the adult form, do so at the pace, and with the result permitted by the available environment. Acute mal-nutrition or illness may temporarily deviate the child from its normal course, but as soon as the conditions causing this deviation are removed, a "restoring force" (Tanner 1970) develops which pushes the child back towards its original course. This thrust towards recovery may have great velocity, but it decreases once the child gets back on its normal course towards its goal of maturation. This property of 'self-correction' and 'goal-seeking' is shared by living organisms and complex inanimate systems that are in continuous interaction with their surroundings. This property is called 'canalization' or 'homeorchesis' (maintenance of a flowing or developing situation) by Waddington (1957).[1]

The period of growth and development is also marked by sensitive or critical periods. These periods are characterised by "a certain stage of limited duration

---

1. Waddington, C.H.1957. The strategy of the genes. A discussion of some aspects of theoretical biology. Allen & Unwin, London.

during which a particular influence, from another area of the developing organism or from the environment, evokes a particular response."* This response may be beneficial, or necessary for normal growth and development, or damaging to the organism. These sensitive periods are not fixed points but ranges of sensitivity which are minimal at the beginning and end of the periods and maximum towards the middle of it.

An example of it is the period of the first trimester of the prenatal life of the human fetus, when if the mother is infected with german measles, there is every chance of the fetal development being affected and the child being born defective. These periods are less in evidence in the post natal physical growth as far as our present knowledge goes. "Certainly there is a formal analogy between 'readiness' to read, for example and competence in brain systems. It seems likely the connection will be shown to be more than formal when research on brain growth has advanced".** (Tanner, 1970).

Organization of growth shows itself in the presence of maturity gradients. For example the foot is nearer adult maturity at a given point in childhood than the calf;

---

* Tanner J.M.(1970) op.cit. p.131.

** Tanner J.M.(1970) op.cit. p.132.

and the thigh is even farther. Many of these maturity gradients are identified. They cover small areas and are operative for short periods of time. There are others that encompass whole systems and operate throughout the growth period. The head is always more mature than the trunk and the trunk more so than the limbs. The ordinal position of the gradients in a particular part of the body is the same irrespective of the sexes. This is clearly illustrated in Tanner (1970).* In the hand and foot, the second digit is the most advanced and are followed by third, fourth and fifth, in that order.

Tanner also states the concept of 'spiralling' with regard to physical growth in his discussion. Carrying further his analogy of the self-correcting control system he states that at adolescence the greatly increased sex hormone secretion is initiated and appears to be controlled by a previously established feed-back circuit which is greatly enhanced in an encompassing fashion at this time. Tanner believes that "behavioural patterns also seem to develop by reverberation and amplification of earlier-laid-down behaviours, perhaps with the objects changed and the emotions renamed."**

---

* Fig.No.34, p.132 in Tanner J.M.(1970).

** Tanner, J.M.1970. Op.cit. p.133.

Prenatal Growth :

Life begins at conception and not at birth, is a fact which has been established a long time ago. In spite of the mounting evidence that growth in utero plays a very important role in the future of the child, for reasons easily understood, very little is known, about this period. For example, one of the areas of our ignorance is knowledge about the forces that select one sperm out of millions to fertilise the ovum ! After fertilisation, in one of the two fallopian tubes, it takes the ovum seven days to attach itself to the uterine wall after a period of floating in the uterine cavity. At this time it is called a blastocyst and is made up of steadily dividing cell which number several dozens at this stage. After implantation the outer layer develops into the placenta and a small portion of the innerlayer develops into the embryo. The period of embryo is considered to be two to eight weeks after fertilization; during this period the main task of cell differentiation takes place. At the end of this period, it is recognizable as a human with arms and legs, a pulsating heart, and a nervous system that shows the beginning of reflex responses to tactile stimuli. Now it is called a fetus. It is about 3 cms. long.

The embryonic stage of human development is wrought with many dangers. It is estimated that about 30% of the embryos are aborted, usually without the mother's knowledge. This is thought to be nature's way of taking care of 90% of developmental abnormalities, either of embryo or of its protective and nutritive surroundings.

Peak velocity* in height growth is reached at about 4 months post-menstrual age. The velocity is relatively slow in the embryonic age. At the age of 6 fetal months, the velocity starts to drop sharply. By the seventh fetal month, cell-differentiation is largely completed and cell proliferation becomes vigorous. By now the major part of the division and addition of new cells is complete, and postnatally the growth of some tissues is chiefly one of development and enlargement of existing cells. This biological dictatorship continues through adolescence till growth is complete.

The rate of the growth of the fetus is also affected by the uterine environment, especially its limited space. The rate of the growth in weight reaches its peak at about 34.0 weeks post-menstrually (Gruenwald (1967). "There is a significant negative correlation

---

* Thompson, D'A.W.1942. On growth and form. Cambridge: University Press, 1942.

(His and Russow's cross-sectional data analysed by D'A.W. Thompson and curves redrawn by Tanner).

between length at birth and length increments during the first year, and also between weight and weight increment."* According to Tanner etal, (1956)[1] the correlation between length at birth and adult height is only about.3; but by the time the infant is 2 years of age, this correlation between length at 2 and adult height has increased to nearly .8.

Poor maternal nutrition results in lowered birth weight in the humans. According to Gruenwald, (1967)[2] this seems chiefly due to reduced velocity of growth because of poor nutrition in the last two to four weeks of intra-uterine life, because the weights of babies born at this time, around the world under differing circumstances are rather similar.

Birth and Premature infants :

The dramatic event of birth is accompanied by significant change in some prenatal physiological functions. Establishment of respiration and pulmonary circulation are the two chief events that take place at birth. Uptill now, failure to establish respiration soon after birth was considered to result in neonatal death or brain injury

---

1 Tanner, J.M.Healy, M.J.R.,Lockhart, R.D., Mackenzie,J.D. and Whitchouse, R.H.Aberdeen Growth Study, I. The prediction of adult body measurements from measurements taken each year from birth to 5 years. Archieves of Diseases in childhood, 31, 372-381. 1956.

* Tanner, J.M.1970. Op.cit. p.91.

2. Gruenwald, P.1967. Growth of the human fetus. In A. Mcharen (Ed). Advances in Reproduction Physiology,Vol.II. London. Logos.

amongst the survivors. Knobloch and Pasamanick (1962)[1] give evidence suggestive of pre-existing brain damage resulting in interference with adjustment to extra-uterine life and failure to breathe soon after being born.

There is additional evidence from Drillien 1964 [2] which throws more light on this problem. In her study she shows that the more severe deffects in the prematurely born infants originate in the early months of pregnancy rather than during the last trimester or at the time of delivery.

However, there is some evidence of differences in later behaviour of those who suffered some birth injury and those who did not.

There are changes in some enzyme systems at birth and on the other hand some enzyme systems like the foetal hemoglobin are not at all affected by the fact of birth. Above all the maturation of the nervous system seems to be little affected by birth. Drayfus - Brisac 1966; [3] and Minkowski 1966 [4] have shown that the electroencephalogram of an infant born at 28 weeks is much the same as that of one born at 34 weeks, 6 weeks later.

---

1. Knobloch, H., and Pasamanick, B.1962. Mental subnormality. New England Journal of Medicine. 266, 1045-1051; 1092-1097; 1155-1161.
2. Drillien C.M.1964. The Growth and Development of the prematurely born infant. Edinborongh: Livingston.
3. Dreyfus-Brisac, C.The bioelectrical development of the central nervous system during early life. In.F.Falkner (Ed). Human Development. London:Saunders, 1966.
4. Minkowski, A.Development of the nervous system in early life. In F.Falkner (Ed). Human Development, London, Saunders, 1966.

Papousek (1961)[1] has shown that the data of appearance of the conditioned reflexes is not affected by birth, According to Dargassies (1966) the schedule of motor behaviour remains unaltered by birth.

In light of all this evidence it seems that birth is only a major visible event in human growth and development which began at conception. It is like the curtains parting for the appearance of the major actor who carries on the drama of life.

The definition of premature for those infants born weighing less than 5.1/2 lbs. or 2500 gms. which was declared by WHO in 1948, has now been discontinued and WHO, 1961 has substituted low-birth weight infants for babies weighing less than 2500-2000 gms. at birth. Those born before the completion of their gestation period are known as short-gestation period infants. If the infant falls short of the standard weight for such babies he is known as small-for-date baby.

Drillien (1964) has shown that low birth weight babies have a greater velocity in the first two years but they probably never catch up with those reared under similar

---

1. Papousek, H.(1961). A Physiological view of early autogenesis of so-called voluntary movement. Plzen. lek. 56. Suppl. 3, 195-198.

circumstances but weighing more, either physically or intellectually. Growing less than normally inspite of a full period of gestation "implies a pathology of fetus, placenta or mother",* whereas being born before time is not necessarily pathological.

Growth and Development of the Brain as a Salient Feature of Infancy :

The significance of the growth of the human brain for the total life span can hardly be under-rated. As seen in the following figure most of the brain growth takes place in utero and during infancy. In terms of its potential, knowledge about the growth and development of the brain is minimal. Studies of brain structure are very difficult as a great deal of courage, persistence and technical support are needed to carry out morphological analysis of the brains of children at different ages.[1] For a long time now electro-encephalogram has been the only method of physiological study of the brain. In the last decade or so interest has been mounting in this area of study, and biochemical investigations at various stages of development have begun with animal experimentation,

---

* Tanner, J.M.(1970), p.92.

1. Tanner, J.M.(1970), Op.cit. p.119.

FIG. 1

MAIN TYPES OF POSTNATAL GROWTH OF THE VARIOUS PARTS AND ORGANS OF THE BODY (AFTER SEAMMON: THE MEASUREMENT OF THE BODY IN CHILDHOOD, THE MEASUREMENT OF MAN. UNI. OF MINNESOTA PRESS.)

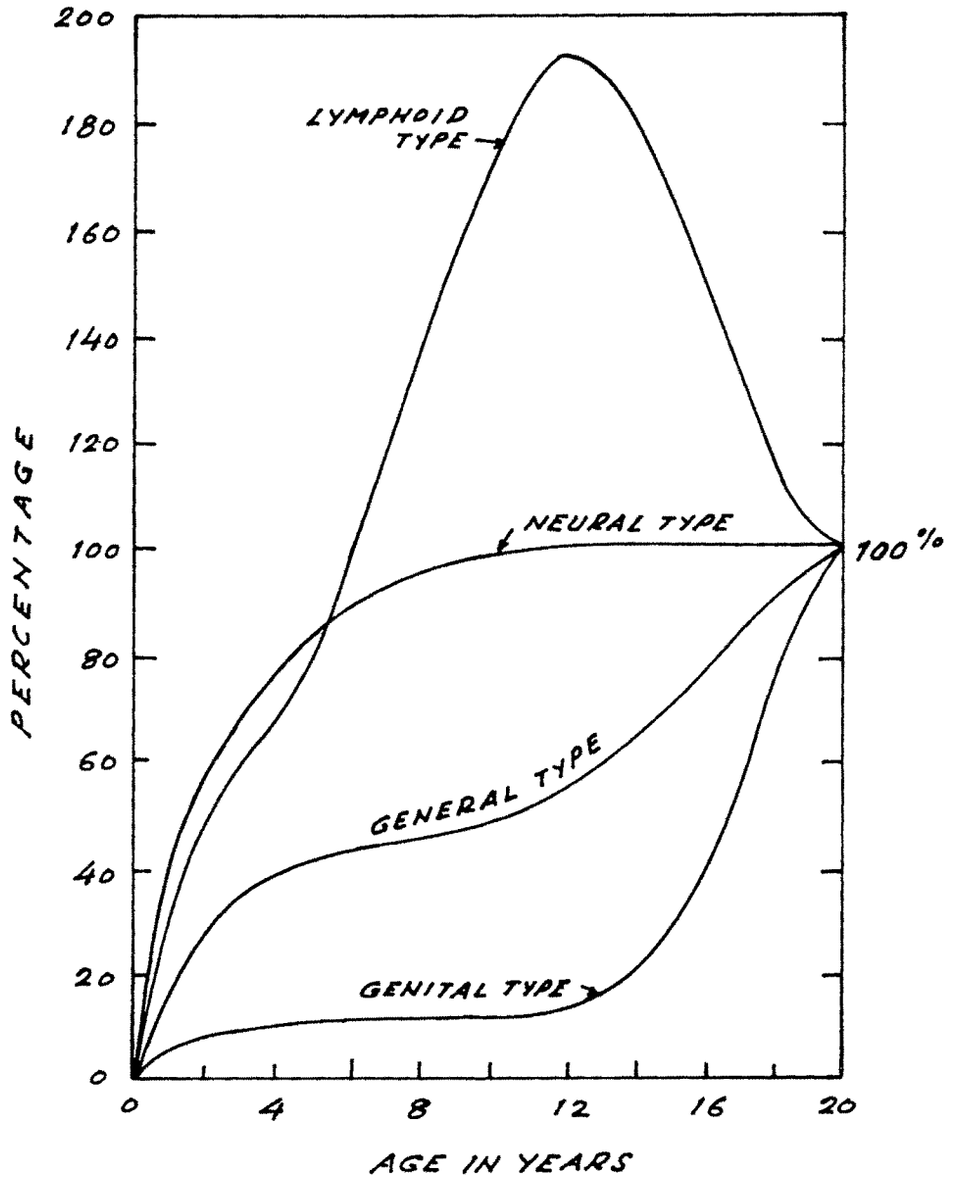


Figure I shows that at birth the human brain has already achieved 25% of its total growth in terms of adult weight and at 2½ years or end of infancy, almost 75%. "Different parts of the brain grow at different rates and reach their maximum velocities at different times."*

The appearance of brain function is closely related to maturation in structure from early fetal life. This link between structure and function is carried over into adult life and "there is every reason to believe that the higher intellectual abilities also appear only when maturation of certain structures or cell assemblies, widespread in location throughout the cortex, is complete."** Tanner also feels that the stages of mental functioning described by Piaget and others have the same characteristics as those of the developing brain and other body structures and the appearance of one stage after another is limited by brain maturation and organization.

There is speculation about 'whether' and 'how much' the brain growth and development are affected by the environment. Cajal, and Hebb seem to think that use of the brain increases its connectivity but there is little

---

* Tanner, J.M.(1970). Op.cit., p.120.

** Tanner, J.M.(1970). Op.cit., p.123.

experimental evidence to support this hypothesis. On the other hand, Douglas (1956)[1] has shown that eventhough prematures seem to reach the motor milestones later in chronological age than full term infants this is not true when their age is calculated from conception rather than from birth. In other words the stimulation offered by the longer extra-uterine life of the premature babies in no way affects their achieving the developmental goals of standing and walking at a certain post fertilization age. And yet, in presence of extreme malnutrition and/or other toxic substances neural growth is definitely affected. The extent to which malnutrition affects brain growth and development is not established by experimental evidence. The fact that brain growth in man and experimental animals is less affected than body growth by post-natal malnutrition is well established. This is mostly accountable by the fact that the brain has achieved a relatively much higher proportion of its growth and development before birth.

---

1. Douglas, J.W.B. 1956. The age at which premature children walk Medical off., 95, 33-35.

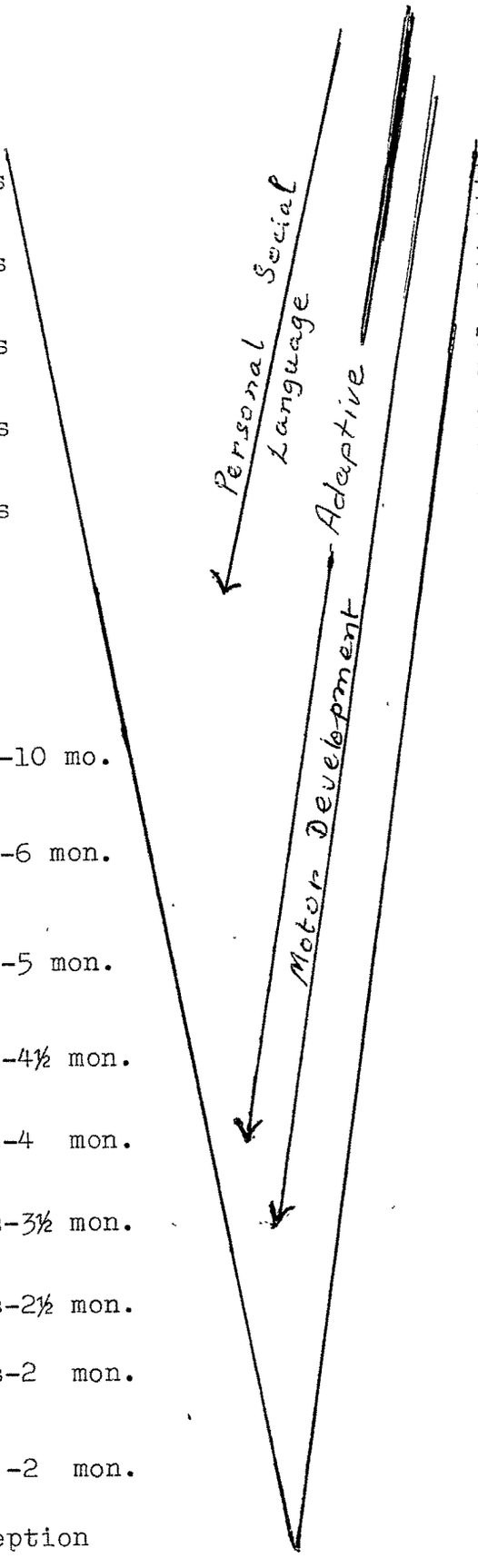
Motor Development :

Motor development in infancy is the most important concrete expression of maturation of the human young. It is in these first fifteen months or so, that the helpless newborn is transformed from the disorganised human to the toddler that resembles the adult human being and very shortly thereafter on mastering the language, he joins the human race as its most junior member.

Gesell[1] gives a very lucid resume of this period of development in a schematic diagram reproduced below. A critical look at the diagram makes it clear that the development is basically related to the structural and functional maturation of the human body.

---

1. Gesell, A. & Frances L.I.G.(1943). Infant and child in the culture of today. Harper & Row: N.Y., p.63.



18	months	Larynx, words, phrases. walks
12	months	legs, feet. Stands, cruises.
10	months	Trunk, fingers, sits, creeps
7	months	Hands, grasp and manipulate
4	months	Head balance
1	month	eyes, ocular control
BIRTH		
40	weeks-10 mo.	Zone of pre term viability
24	weeks-6 mon.	Autonomic system, -physico-chemical control.
20	weeks-5 mon.	Tonic-neck reflex, quickening.
18	weeks-4½ mon.	hand closure, grip.
16	weeks-4 mon.	pre respiratory movements.
14	weeks-3½ mon.	Swallow, sneer, babiuski reflexes.
10	weeks-2½ mon.	trunk extension.
8	weeks-2 mon.	Fetal stage:Trunk flexion, oral sensitivity.
1	week -2 mon.	Embrayomic stage preneural organization.
0	Conception	germinal organization.

Sex as a control variable of growth and development :

Since the human race is bisexual, through out the growth period sex differences crop up, they become more prominent as puberty is approached. Some of these dimorphisms are evident in fetal life, like the obvious one of the external genitals; others are recognizable by their continuous differential rates of growth. One of the major and significant one, from which others arise, is the differential rate of maturing.

Socio-economic class :

There is conclusive evidence, both in the western world and our country, that socio-economic class is a control variable of growth and development, The members of the more affluent section of society being larger in average sizes than in the poorer sections of society. (Tanner, 1962; Graffer and Corbier 1966, Mehta & Merchant).

The causes of this difference are many. Quality of nutrition is a major one. According to Tanner, regular meals, sleep, exercise and generally a well organised home and family life which characterises a child centered attitude is also important. These home conditions reflect

---

Eveleth, P.B.1966. Eruption of permanent dentition and menarche of American Children living in the tropics. Human Biology, 38, 60-70.

Tanner J.M., 1970. Op.cit.

the intelligence and personality of the parents. It is also observed that from amongst the children coming from the same background, the more intelligent children are taller at all ages than the less intelligent ones. This association probably reflects a complex mixture of the genetic and environmental effects and their interaction with each other.

Number of Children in the Family :

Even to the casual observer of our country's population characteristics, it must be obvious, that in our society, larger families characterise the poorer section of the community in recent years. These families also suffer from lack of education and other environmental deprivations. Besides, the more mouths to feed the less individual attention in matters of food, clothing, and education, for the child; is the rule rather than the exception in these families.

Nutrition :

The discussion so far has squarely put nutrition at the centre of the environmental factors affecting growth and development, directly or indirectly.

The effects of nutrition differ on rates of growth, on final size, and on shape and tissue composition (Tanner 1970)[1]. Size and rate of growth are much more easily affected than shape and tissue composition.

If the episodes of starvation are acute and of short periods, the retardation of growth and development in children reverses and they are able to come back to their normal course on the growth curve. This was clearly shown by the many studies done in Europe during the IInd World War.

Chronic malnutrition presents a totally different picture. One visit to a large hospital's outdoor clinics in our country is enough to collect evidence for blindness due to vitamin A defficiency or ricketts due to vitamin D and calcium. Any number of defficiency diseases can be spotted.

Nutrition has a still different effect on the very young child and infant, as the classic studies of infants and young children in orphanages point out. More recently, Powell et. al., 1967[2] in two studies show the effects of extreme psychological trauma described as "deprivation

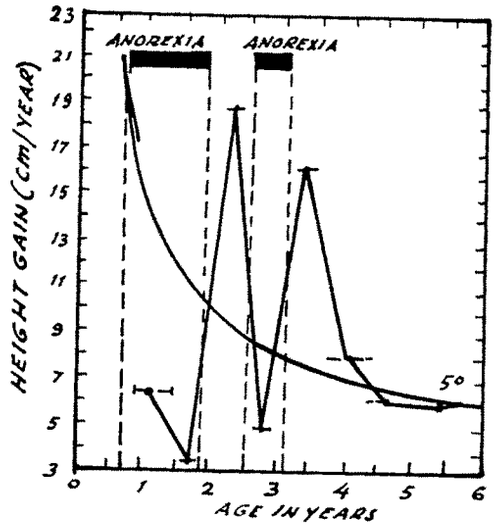
---

1. Tanner, J.M.(1970). Op.cit.
2. Powell G.F., Brasel, J.A. and Blizzard, R.M.1967. Emotional deprivation and growth retardation stimulating, idiopathic hypopituitarism I Clinical evaluation of the syndrome. New England., Journal of Medicine. 276,1270-1278.

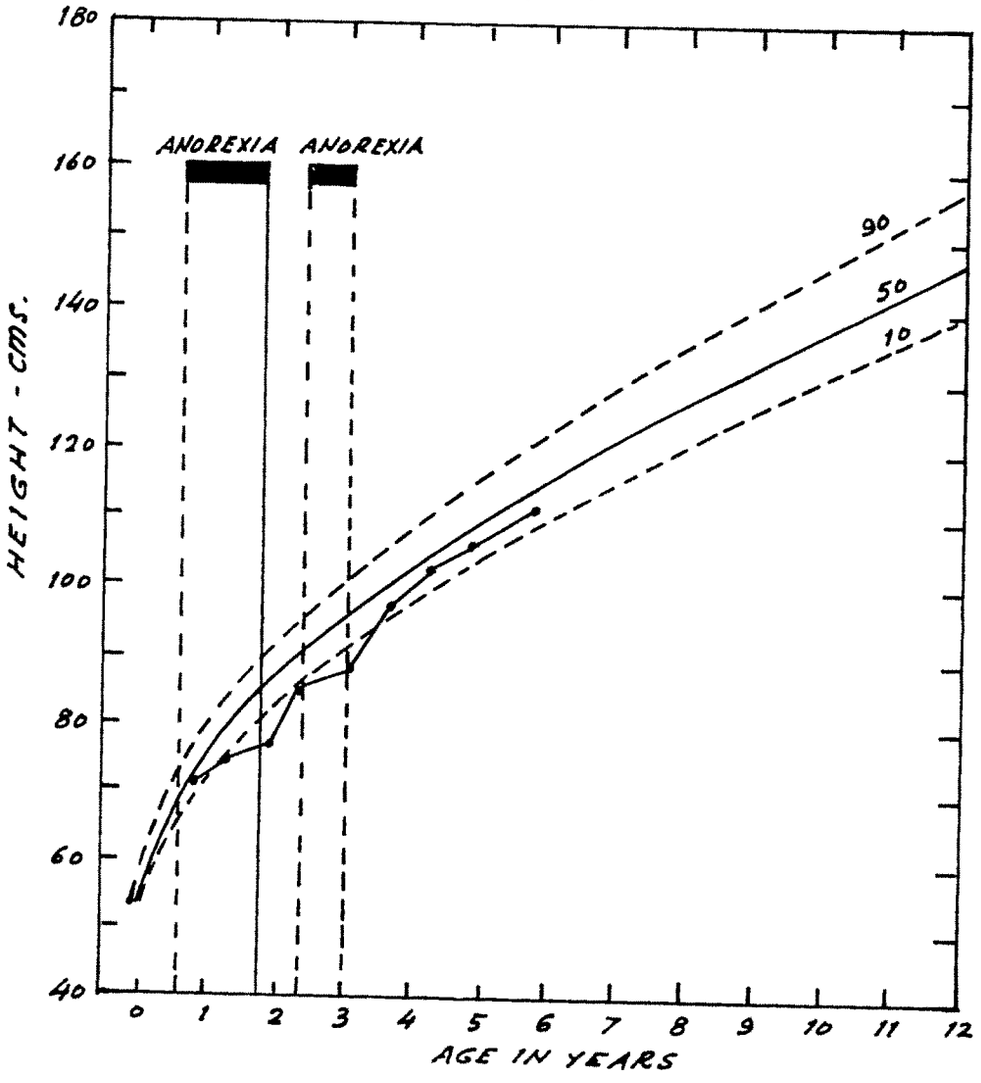
FIG. 2

40

TWO PERIODS OF CATCH-UP GROWTH FOLLOWING EPISODES OF ANOREXIA NERUOSA IN A YOUNG CHILD. (FROM PRADER, TANNER & VON HARNACK, 1963.)



(a)



(b)

dwarfism." These children when removed from their adverse circumstances and restored to conditions more favourable promptly cought up with their status without any other treatment. In another study, Widdowson 1951,[1] describes the surprise discovery of the effect of mental stress in orphanages in Germany. Here, in spite of the increased rations the rates of growth of the experimental group were lower than those of the control group of children. This role played by the emotional components of growth supercedes the role of nutrition in the adequate growth and development of infants and very young children. In other words, nutrition can be effective only if the emotional climate surrounding the infant is at least at minimal levels of comfort. As mentioned before the condition of marasmus is another example of this.

More specifically, contrary to beliefs untill now, proportion of limb to trunk remains the same in the different populations eventhough their overall size may change due to nutrition (Greulich, 1957). This ratio is genetically controlled.

Boys are more affected by malnutrition than girls.

The most important question of the effects of chronic or acute malnutrition in utero and infancy on brain growth and development needs further research.

---

1. Widdowson, E.M.1951. Mental Contentment and Physical Growth. Lancet, 1, 1316-1318.

Genetical programming of growth and development :

The role of genetics in general has been noted earlier. The genetic force not only supplies the potential characteristics but it also determines the time factor of their fruitation. This process is known as genetic programming. This genetic control operates through out the growth period. What is true regarding the age of menarche is also true about skeletal maturity at all ages. As early as 1943, Reynolds[1] showed that there was a correlation of .71 in age of first appearance of centres of ossification in 6 pairs of identical twins, .28 in 22 pairs of siblings and .12 in 8 pairs of cousins. Garn and Rohmann 1962[2] reported correlations of .2 to .5 in parent offspring relationship of age of epiphysial ossification appearances.

The age of erruption of teeth is also genetically controlled to a large extent. (Garn, Lewis and Kerewsky 1965).[3] The sequences of tooth erruption, and the appearance of ossification centers are also, and to a greater extent, genetically controlled. (Garn 1962 and Garn, Lewis and Polacheth, 1960).[4]

1. Reynolds, E.L.1943. Degree of kinships and pattern of ossification. American Journal of Physical Anthropology. N.S., 1, 405-416.
2. Garn, S.M.& C.G.Rohmann 1962. Parent-child similarities in hand-wrist ossification. American Journal of Diseases in childhood. 103, 603-607.
3. Garn, S.M., Lewis, A.B. and R.S.Kerewsky 1965. Genetic, nutritional and malnutritional correlates of dental development. Journal of dental Research. 44, 228-242.
4. Garn, S.M., Lewis, A.B. & D.L.Polacheck 1960. Sibbling similarities in dental development, Journal of Dental Research, 39, 170-175.

"There is considerable evidence that in general, genes controlling rate of growth are wholly or mostly independent of those controlling the final size attained".* On the other hand, body shape as distinct from body size is under normal circumstances, somewhat related to rate of growth. In general early maturers are mesomorphic and late maturers ectomorphic. This relationship is not radical but only adds finishing touches to the potential shape.

All genes are not active at birth. Some are 'age limited' or become active at a certain age. This is evidenced by the increasing similarity between offsprings and parents as growth progresses.

Having reviewed the important aspects of infancy as known today, it is appropriate to proceed to discuss methodology pertaining to studies of physical growth. This follows in the next chapter.

---

* Tanner 1970. Op.cit., p.135.