

## Concept of Human Physical Growth and Development

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### Introduction

Growth is a dominant biological activity during the first two decades or so of human life, including, of course nine months of prenatal life. While growing the individual also matures. Growth is an increase in the size of the body as a whole or the size attained by specific parts of the body. It is a fundamental characteristic of all living organisms. Growth is a form of motion.

The term development is frequently used along with growth and even considered synonymous by some people. But growth and development are not the identical. Therefore it requires a careful examination and proper understanding.

The child is characterized by two fundamental facts – the growth and the development. Growth means the increase in the size of the various parts and organs of the body by multiplication of cells and intercellular components during the period commencing from fertilization to physical maturity. Changes in size are outcomes of three underlying cellular processes: (a) an increase in cell number or hyperplasia; (b) an increase in cell size or hypertrophy; (c) an increase in intercellular substances or accretion. Hyperplasia, hypertrophy and accretion all occur during growth, but the predominance of one or another process varies with age and the tissue involved. The increase in number is a function of cell division (mitosis), which involves the replication of DNA and the subsequent migration of the replicated chromosomes into functional and identical cells. The increase in cell size involves an increase in functional units within the cell, particularly protein and substrates, as is especially evident in the muscular hypertrophy that occurs with regular resistance exercise.

According to Watson and Lowery “ growth means an increase in the physical size of the whole or any of its parts.” It can be measured in terms of centimeters and kilograms or metabolic balance i. e. retention of hydrogen and calcium in the body. Juan Comas defines it “ as the objective manifestation of hypertrophy and hyperplasia of the organism constituent tissues and is determined by post natal body size.” This increase in body size is limited by predetermined constitutional and hereditary factors. It is however influenced by exogenous factors like diet, climate, race, environment etc.

Development refers to the increase of functional capacity in perfect form resulting from production of specialised tissues from unspecialised ones. The term development has been variously defined by scientists. Comas (1960) regards development as a quality peculiar to living matter that carries it through the process of progressive evolution to a state of perfect function. Hurlock (1941) considers development as changes in its progressive series which are orderly and coherent and which lead to maturity. It is, in fact, the consequence of cellular differentiation that the character and its specificity results into perfect function.

An individual may grow in size but some organs though fully grown in size may fail to develop to perform the specific functions. In both growth and development interactions of several processes with each other are involved.

Watson and Lowery (1960) have tried to distinguish between the two processes. They say that growth may mean increase in physical size of the whole or any of its part which may be measured. On the other hand, development indicates an increase in skill and complexity of function. In any case the processes of development and growth are not the same but are interrelated and interdependent.

Maturation is more difficult to define than growth. It is often described as the process of becoming mature, or progress toward the mature state. Maturity, however, varies with the biological system considered. Sexual maturity is fully functional reproductive capability. Maturation refers to the tempo and timing of progress toward the mature biological state. Variation in progress over time implies variation in rate of change.

It should be evident that growth and maturation are closely related. Both are target-seeking and must be viewed as dynamic. The target is the adult state - maturity - and these processes imply movement toward it from the moment of conception until it is attained. Hence, growth and maturation may also be viewed as processes that are purposive, or directional.

The terms growth and maturation are often used in conjunction with the term development. The latter denotes a broader concept often used in two distinct contexts. The first context is biological, and here development is the differentiation of cells along specialized lines of function. This mainly occurs early in prenatal life when tissues and organ systems are being formed, and it is highly dependent upon the activation and repression of genes or sets of genes. The development of function obviously continues postnatally as different systems of the body become functionally refined.

The second context is behavioral and relates to the development of competence in a variety of interrelated domains as the child adjusts to his or her cultural milieu – the amalgam of symbols, values, and behaviours that characterize a population.

### **Linear or Distance growth**

It is overall growth at some point of time. Gradually, with time, there occurs increase in height and weight of a child which can be revealed by measuring at some point of time.

### **Growth Velocity or Rate of Growth**

It is increment in growth in a unit of time. The comparison of child's height and weight with the growth-chart helps to determine if the particular child is within the expected normal range for his sex and socio-economic stratum. It does not show whether the child's growth was normal in the recent past. Measurement of velocity of growth is more fruitful. It helps in early assessment of retarding factors of growth as well as prediction of ultimate growth.

## **STAGES OF GROWTH**

The stages or phases of growth have been classified in different manners by different researchers.

### **Prenatal Period**

The prenatal period comprises, on the average, about 10 lunar months (there are 28 days in a lunar month), 9 calendar months, or 40 weeks. A fertilized egg of a multicellular animal is transformed into an embryo by cell division, growth and differentiation. This growth into the embryo is called prenatal growth. In the prenatal period (before birth) the embryo is formed with rudiments of all organs and systems.

Prenatal growth has three distinct stages: the fertilized ovum (egg), or zygote (first 2 weeks); the embryo (from 2 to 8 weeks) and the foetus (from 2 to 10 lunar months).

The human ovum at conception is about 0.1 mm in diameter. During the first part of this period (ovum), it is like a homogeneous mass. During the embryonic stage, though the rate of growth is slow, yet during this time the differentiation process in the mass to form various regions which later on give rise to different parts, like head, arm, leg and others starts. By the eighth week the embryo becomes child-like in appearance. During foetus stage the rate of growth in length as well as weight is considerably high.

### **Postnatal Period**

Postnatal growth is commonly divided into the following age periods.

#### ***Infancy***

Infancy comprises the first year of life. This is a period of rapid growth in most bodily systems and dimensions and rapid development of the neuromuscular system.

After birth, the growth is oriented towards functional state of life. Growth is mainly by addition of more cells or increase in the protoplasm. It can be said that anabolic processes exceed catabolic processes and there is increase in size, shape and weight. This characterizes the infant stage.

Immediately after birth the rate of growth increases. In case weight the peak velocity is reached at two months after birth. The cells become larger in size. The cervical and lumbar curvatures of the spinal column appear as the baby begins to straighten the head and tries to sit up and to stand. During infancy growth is very rapid. More than 50 percent of birth length and 200 percent of birth weight take place during the first year of life.

#### ***Childhood***

Childhood ordinarily spans from the end of infancy (the first birthday) to the start of adolescence. The infant attains childhood before reaching adolescence. It is often divided into early childhood and middle childhood. The early childhood is the period of eruption of milk teeth. The middle childhood (7 to 10 years) is the period of eruption of permanent teeth, though not all erupt. The late childhood starts from the prepubertal period and continues up to the time of puberty. Childhood is period of relatively steady progress in growth and maturation and rapid progress in neuromuscular or motor development.

## ***Adolescence***

After childhood comes adolescence period. The adolescence period extends from the time of puberty upto around 20 years. In this period of life, the hormonal influences play a leading role in order to attain sexual maturity. During this period there is a marked acceleration of growth which is known as adolescence growth spurt. The adolescence spurt is a constant phenomenon and occurs in all children, though it varies in intensity and duration from one child to another. In boys it takes place, on the average from age 12 to 15. In girls the spurt begins about two years earlier than in boys. Differentiation in primary and secondary sexual characteristics marks the adolescence period. There are changes in the reproductive organs, in body size and shape, in the relative proportions of muscle, fat and bone and in a variety of physiological functions.

At adolescence sex differences in physical increase greatly, due chiefly to the differential action of hormones, gonadal and other. Men become considerably larger, acquire broader shoulders, a deeper larynx; women enlarge their pelvic diameter and deposit fat in various strategic places, including the breast.

### **Hormonal Basis of Adolescence**

Adolescence is intimately linked to the secretion of sex hormones in boys and girls. The male sex hormone is testosterone secreted by the gonad, testes. The female sex hormone is oestrogen secreted by ovary. The gonads, ovary and testes are stimulated by pituitary hormones, called Follicle stimulating hormone (FSH) and Luteinizing hormone (LH). Together, these are called gonadotrophins. The pituitary hormones, FSH and LH, in turn are controlled by hormones of specialized region of brain, called hypothalamus. Hypothalamus secretes gonadotrophin releasing hormone (GnRH). Under appropriate internal and external signals, GnRH is released from hypothalamus that has effect on pituitary causing release of gonadotrophins. Gonadotrophins act on gonads and effect release of testosterone and oestrogen in males and females respectively.

### ***Physiological Changes***

Changes in physiological function occur during adolescent spurt. They are much more marked in boys than girls and serve to confer on the male his greater strength and physical endurance. Before adolescence boys are on average a little stronger than girls. After adolescence boys are much stronger, chiefly by virtue of having larger muscles. Boys have larger hearts and lungs relative to their size, a greater capacity for carrying oxygen in the blood, and a greater power for neutralizing the chemical products of muscular exercise. In short, the male becomes at adolescence more adapted for the tasks of hunting, fighting and manipulating all sorts of heavy objects, as is necessary in some forms of food gathering.

There occurs in the boys an increase in the number of red blood cells at puberty and consequently in the amount of hemoglobin in the blood. No sex difference exists before adolescence. The systolic blood pressure rises throughout childhood, but this process

accelerates in boys at adolescence; the heart rate falls. The alveolar carbon dioxide tension increases in boys and not in girls, giving rise to a sex difference in the partial pressure of carbon dioxide in arterial blood. Coincidentally, the alkali reserve rises in boys. Thus, the blood of an adult man can absorb during muscular exercise, without change of pH, greater quantities of lactic acid and other substances produced by the muscles than that of a woman – a necessity in view of greater relative development of muscular bulk in the male.

As a direct result of these anatomical and physiological changes the athletic ability of boys increases greatly at adolescence.

## **Maturity**

In the adolescent period of life, the hormonal influences play a leading role in order to attain sexual maturity. The endocrine glands under the direction of pituitary hormones prepare the body for adulthood. An important sign of maturity is reproductive maturity. During adolescence reproductive maturity begins but not completed. The active reproductive period extends upto 40 or 45 years of age in the human beings. The cessation of growth of height is also regarded as a sign of maturity.

There have been found biological criteria for maturity. There are three such criteria. 1. Skeletal Maturity, 2. Dental Maturity, 3. The shape age.

### ***1. The Skeletal Maturity :***

Bones show gradual development in its histologic structure. There appears first a main ossification center and gradually, with time, there appear many subsidiary centers that fuse with the main ossification centre. Such centres are easily diagnosed in X-rays because ossification centres, because of its high calcium content, make it opaque. The bone-age is calculated by the number of ossification centres as well as stage of its development.

The X-rays of hand bones is matched with the atlas specifying the changes with increasing age and found out to which of the sample in the atlas the radiograph matches. In recent times, there can be found developmental age of each bone. Hence each bone is matched separately and given a score. The total scores thus gained is matched with the range of score of the standard group.

### ***2. Dental Maturity :***

It is calculated on the basis of stages of calcification as seen in the jaw X-rays in just the same way the skeletal maturity assessment through radiograph.

### ***3. Shape Age :***

Shape age is difficult to derive and is a research problem. Mere calculating height or weight or IQ do not give any indication of age. In shape age, a combination of body measurements are taken into account, all of which change with ages but independent of final size and shape. It should not concern us here because, as already stated, it is a research problem. Individuals are characterized by several maturational characteristic.

### **Senescence :**

After the active phase in the span of life, there is a declining process resulting in old age or senescence. During this period many molecular and cellular changes occur. There are also organismic changes. These changes are measurable and can be explained, but these do not exhibit any specific pattern or well-defined sequence. It seems that a multi-causal mechanism is involved in this process.

In some individuals the changes are fast; in others slow. Individuals are characterised by several senescent characteristics such as graying of hair, loss of strength, reduction in sensory capabilities, poor homeostatic mechanisms, reduced resistance of body against the diseases, cardiovascular irregularity and several other criteria. Like maturity characteristics, the senescent characteristics also appear at different chronological ages. A person at 35 years of age may suffer from graying of his or her hair, loss of homeostatic mechanisms and a cardiovascular irregularity. In such cases, chronological age of the person is low, but his or her biological age is much advanced. For late maturers, however, biological age is generally lower than chronological age.

#### **Ageing and senescence : theories and observations – biological and chronological longevity**

The term senescence is used when talking about the changes which occur during the period of obvious functional decline in the later year of life-span. Some people use the term ageing for the same processes and period. Others use it in a much general way, with ageing meaning simply growing older, and ageing changes being any changes related to age, regardless of when in the life span they occur. Thus, the onset of puberty might be described as an ageing change, but not as a senescent change.

However, there have been many formal definitions of ageing processes and senescence. According to Strehler (1962), “Senescence is the changes which occur generally in the post-reproductive period and which result in a decreased survival capacity on the part of the individual organism.”

According to Maynard Smith (1962), “Ageing processes are those which render individuals more susceptible as they grow older to various factors, intrinsic or extrinsic, which may cause death.”

According to Comfort (1960), “Ageing is an increased liability to die, or an increasing loss of vigour, with increasing chronological age, with the passage of the life cycle.”

It is evident from definitions that senescence has at least three cardinal characteristics. Firstly, the changes that occur during ageing are deleterious; they increase the chances that an animal will die. Ageing, therefore, involves a decrease in the ability of an animal to cope with its environment. Secondly, the deleterious age-related changes are cumulative. Death, the ultimate result of ageing, is sudden, but the process of ageing involves a progressive increase in the probability of dying. A third characteristic of ageing and senescence, which is implicit in most of the definitions which have been given, is that the processes involved are common to all members of a species and are inescapable consequence of getting older. That is to say, ageing and senescence are fundamental intrinsic properties of living organisms.

Ageing is a process involving many changes in the body. There are molecular, cellular and organismic changes. These changes are measurable and can be explained. After the active phase in the span of life, there is a declining process resulting in old age or senescence. It seems that a multi-causal mechanism is involved in this process. Some of the changes are –

1. Decline in metabolic efficiency.
2. Decrease in the power of replacing worn out old cells repairing the damaged tissues, organs and organ systems. A few organs responsible for vital functions may become functionally inefficient.

Manifestation of these changes, as the individual grows older is known as ageing. Thus, ageing may be defined as the deterioration in the structure and function of body cells, tissues and organs of the individual.

### **Theories of ageing :**

Several theories have been put forward to explain the process of ageing.

1. Ageing is due to interaction of the genetic material and the environment, a product nature and nurture combination.
2. Ageing is caused by accumulation of some harmful products of metabolism in the cells and in intercellular spaces. In other words the internal environment of cells undergoes adverse changes resulting in ageing.
3. Ageing is due to intrinsic property of the genetic material ( gene = DNA ) i. e. the programme is already there in the body and it is undergone as predetermined activity.
4. Wear and tear theory suggests that the tissues of the body become wornout because of continuous and constant usage and are not replenished that fast.
5. Very high rate of metabolic activity during life advances old age, and slow rate enhances the lifespan.

Because of ageing the tissues do not renew and as a result cells show senile involution. The memory declines. Aged persons need more time to learn and to react. Systolic blood pressure increases. The speed of conduction in motor nerves shows a decline. The range of accommodation of the eye lens declines. Peripheral resistance and circulation time in the cardiovascular system show an increase. There is reduction of density of long bones and vertebrae, and therefore, height and sitting height show decrease. Vital capacity and muscle tone declines. Arm span circumference of forearm and that of calf diminishes.

Visible changes due to ageing are morphological and physiological. A dry skin shriveled and stooping body with wrinkled skin is often quite visible in old persons. With age the heart's efficiency to pump blood diminishes. Brain and kidneys receive smaller quantities of blood. The quantity of blood passing through the lungs is reduced consequently affecting intake of oxygen. With age the number of taste buds in the tongue and the number of kidney tubules (nephrons) get reduced. Bone marrow does not produce as many new cells as they were producing when the body was young. Cells do not retain water and therefore dry skin, less volume of blood and less urine is formed. Muscles become weak and bones get brittle.

All these changes are mainly due to physical and physiological changes within the cells and intercellular spaces in the tissues. Cellular changes include chromosomal abnormalities and mutations in the genetic material. Inactivation of certain enzymes, productions of defective proteins are all due to increased defects of the DNA structure. Some cells of the brain accumulate worn out cell organelles or pigments. In other words, cells in different parts of the body lose their efficiency. The intercellular proteins especially collagens undergo a marked change in their constitution. These proteins which are permeable, flexible and easily soluble in young persons, become less permeable, rigid and insoluble as age advances. These property changes affect gaseous exchanges and expulsion of nitrogenous wastes.

Gerontologists have worked out quite a large number of changes in cells and in extracellular substances of different tissues of several kinds.

### **Overview of postnatal growth: Scammon's curves**

The curves of systematic growth reported by Scammon about 60 years ago. Upon analysis of the size of various parts and organs of the body, Scammon proposed that the growth of different tissues and systems could be summarized in four patterns (or curves) of growth.

#### **General Curve**

The general, or body, curve describes the growth of the body as a whole and of most of its parts – the growth pattern of stature, weight and most external dimensions of the body. It is also characteristic of the growth pattern of most systems of the body, including muscle mass, the skeleton, (with the exception of certain parts of the skull and face), the

respiratory system, the heart and blood vessels, the digestive system, and the urinary portion of the urogenital system. The growth pattern is S - shaped (sigmoid) and has four phases: rapid growth in infancy and early childhood, steady but rather constant growth during middle childhood, rapid growth during the adolescence spurt, and slow increase and eventual cessation of growth after adolescence

### **Neural Curve**

The neural curve characterizes the growth of the brain, nervous system, and associated structures, such as the eyes, upper face, and parts of the skull. These tissues experience rapid growth early in postnatal life, so that about 95% of the total increment in size of the central nervous system between birth and 20 years is already attained by about 7 years of age. Neural tissues shows steady gain after 7 years of age, with a slight growth spurt during adolescence.

### **Genital Curve**

The genital curve characterizes the growth pattern of the primary and secondary sex characteristics. The former include the ovaries, fallopian tubes, uterus and vagina in females, and the testes, seminal vesicles, prostate and penis in males. Secondary sex characteristics include breast development in females, pubic and axillary hair in both sexes, and facial hair and growth of the larynx in males. Larynx growth is related to voice changes that occur during male adolescence. Genital tissues show slight growth in infancy, followed by a latent period during most of childhood. Genital tissues then experience extremely rapid growth and maturation during the adolescent spurt.

### **Lymphoid Curve**

The lymphoid curve describes the growth of the lymph glands, thymus gland, tonsils, appendix and lymphoid patches of tissue in the intestine. These tissues are involved, in general with the child's developing immunological capacities, including resistance to infectious diseases. Lymphatic tissues show rapid growth during infancy and childhood, reaching a maximum at about 11 to 13 years of age. At these ages, children have, on a relative basis, about twice as much lymphoid tissue as they have as adults. The decline of the lymphoid curve during the second decade of life is related to the involution (shrinking) of the thymus and tonsils at this time.

Scammon's curves thus indicate the differential nature of postnatal growth. Growth occurs in different areas and tissues of the body at different times and at different rates. Although somewhat simplified and diagrammatic, the curves give a sense of order to the structural and functional changes that occur with growth and maturation. Nevertheless, there are several exceptions to the four curves. The craniofacial skeleton is one such exception. The upper part of the face, the orbits of the eyes, and the cranial vault follow the neural curve and complete a good portion of their growth by about 7 years of age. The lower face, including the jaw, follows the general curve. Thus the upper part of the face has a different growth pattern than the lower part.

### **Catch-up Growth**

After illness or starvation which is a period characterized by slow growth, there has been found tendency in the younger subject's to bridge the deficit as soon as possible and catch up with the original growth-curve. This is known as catch-up growth.

The velocity during initial period of catch-up may reach three times the normal for age. The term compensatory growth is sometimes used by nutritionists to describe a similar phenomenon; however, that term was first applied to the quite different phenomenon of the replacement growth of organs or parts. Thus, showing compensatory growth. Catch-up may be complete or incomplete; if the stress has been severe, and particularly if it has been applied early in the animal's life, then even though a catch-up velocity may be established for a while it may be insufficient to return the animal completely to its normal curve of growth.

### **Growth Charts**

Growth charts show progressive changes in height and weight of a child with age. The growth chart depicts average and permissible range of variation for the particular age or attribute. If the growth measurements are recorded in a child over a period of time and are plotted on a graph paper, the deviation in the growth profile of the child from the normal pattern of growth for that age can be interpreted visually.

## **FACTORS AFFECTING GROWTH AND DEVELOPMENT**

The integrated nature of growth and maturation is largely maintained by a constant interaction of genes, hormones, nutrients and other factors. These factors also influence physical performance. Some are hereditary in origin. Others, such as season, dietary restriction, severe psychological stress, originate in the environment and simply affect the rate of growth at the time they are acting. Others again, such as socio-economic class, reflect a complicated mixture of hereditary and environmental influences and probably act throughout the whole period of growth.

### **Genetic control**

The height, weight or body-build of a child or an adult always represents the resultant of both the genetical and environmental forces, together with their interaction. It is a long way from the possession of certain genes to the acquisition of a height of 2m. gene depends for its expression firstly on the internal environment created by all the other genes, and secondly on the external environment.

The control of body size is certainly a complicated affair involving many genes, yet a disturbance in a single gene or group of genes may produce a widespread and drastic effect, as in the condition of achondroplasia, which is inherited as a simple dominant. On

the other hand, the effects may be quite restricted and specific. The genetic control of dental maturation and eruption appears to be separate from that of skeletal maturation, and there is even evidence that the genes controlling the growth of different segments of the limbs are independent of each other.

It is now believed that dental development and the sequence of ossification are primarily genetically controlled; the timing of ossification is partly influenced by genetic factors and partly by environmental ones. Maturation as a whole is even more affected by environment, but genetic influences are still detectable.

It seems that the genetic materials operate throughout entire period of growth. Heredity influenced the rate of growth of early maturers or late maturers. Parent - offspring correlation in regard to height from birth to maturity for each are and sex has been reported. Chromosomal abnormalities suggest genetical control on growth. Genetic factors probably play the leading part in the difference between male and female patterns of growth.

### **Environmental :**

There is a well-marked seasonal effect on velocity of growth visible in most human growth data. Growth in height is on average fastest in spring and growth in weight fastest in autumn. This is true at all ages, including adolescence. The mechanism of the seasonal effect is not known; probably variations in hormone secretion are involved.

Climate seems to have a very minor effect on overall rate of growth in man. It has been suggested that each major race of mankind varies in stature according to the climates in which they live.

Seasonal variation in growth has also been observed in many studies. Longitudinal studies have shown that only about 30% of the children have cycles of increase and decrease in growth velocity which are strictly seasonal. The remaining children show accelerations and decelerations of growth which can not be clearly related with seasons.

### **Endocrine regulation**

Endocrine glands are commonly referred to as ductless glands, or glands of internal secretion. They secrete chemical substances, hormones directly into the bloodstream. Human growth is affected by biochemical products such as hormones. Hormones are regarded as growth promoting substance. Probably all the endocrine glands influence growth. Most of the hormones are secreted by the endocrine glands and play a significant role in regulating the pattern of growth and development as per instructions of the genes.

The most important hormone controlling growth from birth up to adolescence is growth hormone or somatotrophin. This is infact a polypeptide secreted by the pituitary. It helps growth of bones and thereby increases the height of persons. Growth hormone controls the rate at which growth takes place upto the time of steroid - induced adolescent spurt.

Its administration causes the amino acids to be incorporated into tissues to form new protein. It also causes an over all growth rate of most of tissues including brain.

Thyroid hormone plays a vital role throughout the whole of growth. The activity of the thyroid, judged by the basal metabolic rate, decreases gradually from birth to adolescence. In hypothyroidism growth is delayed, skeletal maturity, dental maturity and growth of the brain are all affected.

During adolescence a new phase of growth occurs under the control of steroid hormones secreted by the adrenals and gonads. The gonads of both sexes secrete estrogens in small quantities from the time of birth onwards. At puberty the estrogen level rise, sharply in girls and to a much more limited extent in boys; the sex differences is possibly due to an inhibitory hormone secreted by the seminiferous tubules of the testicle. Testosterone, produced by the testicle, is important in stimulating growth and it is responsible for the greater growth of muscle. Gonadotrophins are responsible for the growth of the ovaries and testis, and later on the secretion of the amounts of estrogens and testosterone responsible for the growth and development of secondary sex characters.

### **Nutritional**

Growth is closely related with nutrition. A sufficiency of food is essential for normal growth. An adequate supply of calories is naturally essential for the normal growth of humans and the need varies with the phase of development.

Nine different amino acids have been claimed to be essential for growth and absence of any one will result in disordered or stunted growth. Other factors are also essential for growth. For example, zinc plays a part in protein synthesis and is a constituent of certain enzymes; a deficiency of zinc causes stunting, interference with sexual development and falling out of hair.

Iodine is needed for the manufacture of the thyroid hormones. Bone will not grow properly without an adequate supply of calcium, phosphorus and other inorganic constituents such as magnesium and manganese. Iron is required for the production of haemoglobin.

Vitamins play an important part in growth. Vitamin A is thought to be control the activities of osteoblasts. In vitamin C deficiency the intercellular substance of bone is inadequately formed. Vitamin D deficiency is the cause of rickets.

Malnutrition during childhood delays growth, and malnutrition in the years proceeding adolescence delays the appearance of the adolescent spurt. Growth studies have demonstrated that malnutrition may cause serious impairment of growth. The term malnutrition generally refers to the effects of an inadequate intake of calories or other major dietary components such as proteins. Malnutrition may also result from diseases which decrease the appetite or interfere with digestion and assimilation. A majority of

malnourished children fail to achieve their full genetic potential of body growth (both linear and ponderal) and are thus stunted or wasted or both.

### **Cultural**

The physical growth of human beings is definitely affected by cultural factors. Culture differs from ethnic group to ethnic group. The body growth differences correlate with varied cultural groups. The physical growth of the body follows some adaptations in different geographical areas of distribution of the groups.

### **Socioeconomic**

Socioeconomic influence on human growth is also a well known factor. Children from different socioeconomic levels differ in average body size at all ages that have been investigated. The upper groups being always more advanced along the course to maturity.

The cause of this socio - economic differential are probably multiple. Nutrition is almost certainly one, and with it all the habits of regular meals, sleep, exercise and general organization that distinguish, from the point of view, a good home from a bad one. Growth differences are more closely related to the home conditions than to the strictly economic status of the families and home conditions reflect the intelligence and personality of the parents.

Size of family exerts an indirect influence on the rate of growth. In a large family with limited income the children do not get proper nutrition. As a result the growth is affected. The number of children in the family exerts an effect on the children's rate of growth. Children in large families have been shown to be usually smaller and lighter than children in small families. Possibly this is because in large families children tend to get less individual care and attention.

## **LATEST SECULAR TREND**

**1. Increase in height and weight:** Overall economic conditions of world has improved in last 100 years and there is found tendency for children to become progressively larger ay all ages. The trend has been operating since last many years and in some well-off industrialized nations the trend has virtually stopped indicating that children of these societies have attained their full genetic potential.

**2. Extent of increase:** Similar increase in heights and weights of children throughout the world has been registered. It is indicated that there is average increase of 1 c.m. in height and 0.5 k.g. in weight per decade between 1880–1950 in the 5-7 years age group. For adolescent group, the same data increases to 2.5 c.m. and 7 k.g. per decade. It is, however, indicated that maximum average increase occurred in 2.5 years age group though there is only scanty data to prove the point.

**3. Fate of Increase:** This trend of increase in size is still continuing in many parts of the world such as many European and Asian countries. In Japan, this increase has taken a peculiar form. There is average increase in the leg length, though trunk length has remained the same. Thus, trunk to leg length is similar in both Japanese and Europeans, though the former mature earlier and are slightly short.

**4. Earlier Age of Menarche:** There has been rather a fast reduction in the age of menarche. Western European data indicate that it occurred earlier by about 4 months per decade between 1830-1960.

**Out Marriage:** Industrialization, urbanization with concomitant development of transport facilities has brought in high mobility and broken down the boundary of genetical isolates by increasing degree of out marriages. There has occurred a considerable hybridization of height genes. The postulate, however, considers that gene for greater height and gene for shorter height when placed together do not produce a height midway between the two but a height towards tallness. Though a conclusive proof is lacking, initial experiments do show that it is, indeed, so.

## **HUMAN PHYSIQUE AND SOMATOTYPES**

Physique refers to an individual's body form, the configuration of the entire body rather than specific features. The study of physique is a single aspect of an area of study sometimes labeled human "constitution", which involves the interrelationships and interdependency among an individual's structural, functional and behavioral characteristics. The development of physique during growth and its relationships with other variables, such as biological maturation, physical performance, and behavioral development, have been studied less comprehensively in children and youths. Conversely, the study of physique during growth permits a better understanding of variation in adult physique relative to factors that are related to individual differences – variation in rate of growth and maturation.

There have been numerous attempts to classify the varieties of human physique. The reason for this is that different physiques are associated with different diseases and with different temperaments. It is inevitable that the physique of the individual influences his occupation in certain cases, his social attitudes and his entire behaviour and success or failure in society. No student of the human constitution doubts the strong correlation between the physique of the individual and his behaviour. The system of individual sorting by combinations of stature and weight seems to be very important behaviorally.

### **Sheldonian Somatotypes**

The conceptual approach of William Sheldon to the assessment of physique is perhaps the approach most commonly used today. Sheldon, an American psychologist recognized three different components of physique. The term "somatotype" is used by Sheldon to designate the 79 varieties of human physique recognized under his system. Sheldon's method is based upon the premise that there is continuous variation in the distribution of

physiques, related to differential contributions of three components to the conformation of the entire body. The different somatotypes are determined by the varying expression in the individual organism of three bodily components of structure: endomorphy, mesomorphy and ectomorphy. The basis of his classification is embryonic germ layers. To him the degree of development of the endoderm, mesoderm and ectoderm determines the body type.

Endomorphy implies a trend toward the predominance of soft roundness throughout the different regions of the body and particularly a massiveness of the digestive viscera. It is so named because the digestive viscera are derived embryologically principally from the inner germ layer, the endoderm. Mesomorphy refers to the accentuated development of certain body structures derived from the embryonic mesoderm; particularly bone, muscle and connective tissue. Ectomorphy means predominance of surface area relative to bulk and of the brain and central nervous system relative to mass. When ectomorphy is in the ascendancy, the body build type is linear and fragile. The contribution of each component define an individual's somatotype.

### **The technique of somatyping**

Sheldon's method is basically photoscopic or anthroposcopic – based on the visual observation and evaluation of the configuration of the body as a whole, its contours, reliefs, relative proportions, robustness, delicateness and so on. The series upon which Sheldon established his somatotyping procedure consisted of 4000 undergraduate male students of Midwestern and eastern universities, ranging in age between 16 and 20 years. He began by taking nude standardized photographs. The photographs consist of front, back and side views of the nude subjects taken at a standard distance, using a long focus lens. Sheldon divided the body for purposes of morphological observation into five areas.

1. Head, face and neck,
2. 2. Thoracic trunk,
3. 3. Arms, shoulders, hands,
4. 4. Abdominal trunk, 5. Legs and feet.

Each extreme represented the end of the distribution of a component. Every individual was then assigned a place in each component. This was done anthroposcopically, using a rating scale of 1 to 7 with equal - sized intervals between the numerals (i.e. the man rated 3 for one particular component appears to be as much more so than one rated 2, as the 2 is more than the 1). Each component in each region is scored from a minimum of 1 to a maximum of 7. Each somatotype is then represented by a three digit combination. For example, 7 - 1 - 1 (extreme endomorphy), 1 - 7 - 1 (extreme mesomorphy), 1 - 1 - 7 (extreme ectomorphy). The whole system is known as "somatotyping". The set of three numerals is a person's "somatotype".

**Criticism :** A number of criticisms can be leveled at somatotyping as a system.

1. First amongst them is that the components are not independent of each other, so that certain theoretically possible somatotypes are not found in practice. Thus there are no people who can be written 7 - 7 - 1 or 7 - 3 - 6, to take only two of many such examples.
2. Somatotyping women also raises difficulties. The same general criteria apply as in somatotyping men, however, and this leads to an excess of high endomorphs in women as compared with men, and a total lack of degrees 6 and 7 in mesomorphy.
3. The independence of widths of bone and muscle is a more serious criticism of the concept of mesomorphy as at present defined, since it includes both wide bones and large muscles. However, it is the size of the muscles that is chiefly used in the assessment, and dropping the bone width from the description would make little difference in practice.

So, Sheldon's method of somatotyping was criticized on the grounds that the photoscopic procedures were too subjective, that the scale from 1 to 7 was arbitrary and limiting, and that an individual's somatotype could change. Hence, several modifications of Sheldon's method were developed.

### **Parnell's phenotype Method**

Richard Parnell's modifications incorporate several anthropometric dimensions to derive a phenotype, which was defined as the physique at a given point in time. Stature, weight, three skinfolds, two limb circumferences, and two bone breadths of the limbs are used to derive estimates of three components – fat (F), muscularity (M), and linearity (L) – in place of Sheldon's endomorphy, mesomorphy, and ectomorphy, respectively. The later terms, however, are used on Parnell's charts. Each component is rated on a 7- point scale, and the phenotype reads essentially like a Sheldonian somatotype.

### **Heath – Carter Method**

Barbara Heath modified Sheldon's method by opening the component rating scales to accommodate a broader range of variation and by establishing a linear relationship between somatotype ratings and stature/weight ratios. She also questioned the permanence of the somatotype through time. The modification was still basically photoscopic, but with the assistance of J. E. Lindsay Carter, Heath subsequently incorporated these changes with the anthropometric procedures of Parnell. The resulting approach is the Heath-Carter method, which combines both photoscopic and anthropometric procedures to estimate somatotype, which is defined as representing the individual's "present morphological conformation." In practice, however, the Heath-Carter method is used primarily in its anthropometric form for the simple reasons that anthropometry is more objective and that obtaining standardized somatotype photographs is quite often difficult and costly.

The three components of somatotype described in the Heath-Carter method are of particular interest because they introduce specific body composition concepts into the

definition of each. This area of study attempts to partition body mass into its lean and fat components – fat free mass and fat mass, respectively.

The first component, endomorphy, or relative fatness or leanness, is derived from the sum of three skinfolds, the triceps, subscapular and suprailiac. The second component, mesomorphy, or relative musculoskeletal development adjusted for stature, is derived from biepicondylar and bicondylar breadths, flexed-arm circumference corrected for the thickness of the triceps skinfold, and calf circumference corrected for the thickness of the medial calf skinfold. The third component, ectomorphy, or relative linearity of build, is based on the ponderal index.

### **Differences among the methods**

The differences among the various methods of assessing physique are obvious. Sheldon's original method is basically photoscopic, whereas his modification results in essentially a different method. Parnell's approach is anthropometric, and the Heath-Carter method in theory combines both the photoscopic and anthropometric procedures, although the latter is most widely used.

## **METHODOLOGIES FOR GROWTH STUDIES**

Growth is in general an exceedingly regular process. Growth may be considered as a form of motion. It is measurable and therefore, anthropometry plays a very important role in the study of growth. The study of growth is important in elucidating the mechanism of evolution. The evolution of morphological characters necessarily comes through alteration in the inherited pattern of growth and development. Growth also occupies an important place in the study of individual differences in form and function in man. Many of these also arise through differential rates of growth of particular parts of the body relative to others.

There are some different methods of studying growth and development. Some important methods are as follows ----

1. Cross - sectional method
2. Longitudinal Method
3. Mixed longitudinal method
4. Extended longitudinal method

### **1. Cross - sectional method:**

In this method the study is completed by observing and measuring different individuals at different phases of their growth, each individual being measured once only, and all the children at age 8, for example, are different from those at age 7. Cross - sectional methods are adequate for studying distributions of various measurements in different individuals at different ages and for constructing standards of growth attained, e. g. height and weight standards.

In case we are interested in the study of pattern of growth of children between 6 to 10 years of age then for each age level we require a sample of say 100 children belonging to 6 years, another 100 belonging to 7 years and so on upto 10 years. The selected measurements are then to be taken for each child who is thus measured only once. This method effectively enabled us to estimate the mean value of any given measurement and also to measure the variation about this mean. This is the most popular method used extensively for working out the population standards and growth charts, particularly for clinical purposes.

Cross - sectional method is the best for the estimation of population mean at successive age levels. This is due to the fact that samples at each age in a longitudinal study are not independent of each other because the children are the same. Therefore, cross-sectional method is the best method for setting up population standards, describing the mean and variation in height, weight or any other parameter in children at different age levels. Moreover, in this method it is possible to measure a large and representative sample for each age group in a short time.

Cross - sectional surveys are obviously cheaper and quicker and can include much larger numbers of individuals. Analysis of such data tells us a good deal about the distance curve of growth that is about height attained at a particular age. On the basis of such data standards of height and weight of a particular population can be fruitfully constructed.

The mean age of reaching a particular maturational stage such as menarche, or the first appearance of pubic hair, or the eruption of a particular tooth, can also be estimated through cross-sectional surveys. Cross - sectional methods are also obligatory in circumstances where continuity is not possible, e. g. – autopsy studies on internal organ.

## **2. Longitudinal Method :**

It is the method of studies growth by observing and measuring the same individual for a variable period, during his/her growth. In longitudinal study each child is measured at each age and therefore, all the children at age 8 are the same as those at age 7. A longitudinal study may extend over any number of years. There are short term longitudinal studies which may cover a couple of years, and a full birth to maturity in which children may be examined once, twice, or more times every year from birth till 20 years.

In this approach measurements are repeatedly done on the same individual or group or individuals at definite age intervals. This is the best way to study the growth of any individual child. It is necessary that the measurements must be correct and accurate. Thus, at the end of a longitudinal study we have a series of measurements for each individual at different age levels. On the basis of these measurements a graph can be plotted for each measurement separately e.g. stature against age for each subject. The graphs obtained in this manner are actually the “distance curves”. If a number of normal

individuals have been repeatedly measured and “distance curves” drawn then similarity in their shapes suggests the pattern of the growth in the stature of the child. The “distance curves”, however, do not indicate as to how quickly the child grows or how slowly he/she grows.

Longitudinal data are greatly preferable for estimating mean velocities of growth. In estimating the variability of the velocity from one year to another longitudinal data are absolutely necessary. Longitudinal studies give correct information on individual variations in the rate of growth, timing of particular stages etc.

Longitudinal studies by their nature are costly, laborious and time-consuming. It depends upon the continuous cooperation of the subjects. In practice it is always not possible to measure the same child at the desired times, because of various reasons. For example, the child may not be available at that time, may leave that place etc. Longitudinal studies are more difficult than the cross-sectional method, since it involves repeated examinations over a period of years.

However, the longitudinal data are essential for the study of growth. It must be admitted that to understand certain basic facts of growth longitudinal studies are unavailable.

### **3. Mixed longitudinal method :**

In practice of longitudinal studies when it is impossible to measure exactly the same group of children every year for a prolonged period. Inevitably some children leave the study, and others, if that is desired, join it. A study in which this happens is called a mixed longitudinal study.

A study will have records that are longitudinal over 2 years for quite a large proportion of its children, over 3 years for a smaller proportion, and over 10 years for a smaller proportion still, perhaps none. It is convenient to refer such data, where some of the children are measured at least twice but some fail to last the specified period and others enter for the first time during it.

In this study special statistical techniques are needed to get the maximum information out of its data. This type of studies is more complicated.

Mixed longitudinal study is applied to a study in which some of the individuals have been measured on at least two successive occasions but have not been present throughout the period of study.

One particular type of mixed study is that in which a number of relatively short-term longitudinal groups are overlapped. Thus one might have groups of ages 0 to 6, 5 to 11, 10 to 16 and 15 to 20 years to cover the whole age range. However problems arise at the ‘joins’ unless the sampling has been remarkably good.

In a mixed longitudinal study the best estimates of mean distance, velocities and accelerations with their standard deviations are made from both the longitudinal and cross sectional elements combined, using Patterson's formulae adapted for growth work by Tanner in 1951.

Mixed longitudinal study is somewhat laborious unless a computer is available.

#### **4. Extended longitudinal method :**

In an extended longitudinal study, a whole series of measurements is available for each child. If these measurements are plotted against chronological age, a curve of growth is obtained. The slope of this "distance – traveled" curve gives a picture of successive increment or velocities. The velocity curve or curve of first differences is obtained by plotting the increments against age.

#### **Measurements commonly used in growth studies**

The general pattern of postnatal growth is quite similar from one individual to another, but there is considerable individual variability in size attained and rate of growth at different ages, with respect both to the body as a whole and to specific parts. Both the whole body and its parts, therefore, must be measured, and the study of growth is synonymous to a large extent with measurement.

Breadth or width measurements are ordinarily taken across specific bone landmarks and therefore provide an indication of the robustness, or sturdiness, of the skeleton. The commonly used skeletal breadths are biacromial breadth, bicondylar breadth etc. Limb circumferences are occasionally used as indicators of relative muscularity. Skinfold thicknesses are indicators of subcutaneous fat, the portion of body fat located immediately beneath the skin. Skinfolds can be measured at any number of body sites. Most often they are measured on the extremities and on the trunk, to provide information on the distribution of subcutaneous fat in different areas of the body. The most commonly used skinfold thicknesses are the triceps skinfold, the subscapular skinfold, medial calf skinfold, suprailiac skinfold etc. Some measurements are useful during particular phase of growth. Head circumference, perhaps the most important, is taken on infants and children, usually to 3 or 4 years of age.