CONCEPT OF HUMAN GROWTH AND DEVELOPMENT

Anthropologist have always been interested in the variation of human across socio-cultural and geographic dimensions. These variations often demonstrate the adaptive responses to the induced environment which involve the basic pattern of growth and development during different phases of lifespan- infancy, childhood, adolescence and adult. Thus, it is important to understand these basic biological processes leading to the disparity among human being.

GROWTH

The British Medical dictionary (1961) defines growth as "the progressive developments of a living organisms or part of an organism from its earliest stage to maturity including the attendant increase in size."

It may be defined as quantitative increase in size of the body as whole or size attained by specific part of the body. The increase in size is a result of assimilation of nutrients into the protoplasm and includes both cell multiplication and expansion of cell cytoplasm. Thus the cellular process responsible for the growth can be summarized as (Malina et al. 2004):

i. Hyperplasia: an increase in cell number It is a function of cell division which involves the replication of DNA and subsequent migration of the replicated chromosomes into functional and identical cells.

ii. Hypertrophy: an increase in cell size 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 during growth.

iii. Accretion: an increase in intercellular substances The intercellular substances are both organic and inorganic, and they often function to bind the cells in complex networks, as collagen fibers provide matrix for the adipocytes of adipose tissue.

These processes occur during growth, but predominance of one or another process varies with age and all the tissue involved.

DEVELOPMENT

Development refers to the progressional change, either quantitative or qualitative, that leads from an undifferentiated or immature state to a highly organized, specialized, and mature state (Bogin, 2002). Growth and maturation occurs simultaneously with development but latter denotes a broader concept within two distinct contexts- biological and behavioural (Malina et al. 2004; Berk 2008)

In biological context, it refers to the processes of differentiation and specialization of pluripotent embryonic stem cell into different cell types, tissues, organs, and functional units. Differentiation mainly occurs early in prenatal life when tissues and organ systems are being formed. Onset of function in a particular tissue characterizes attainment of complete differentiation. The course is regulated by activation or repression of sets of gene interacting with hormones and nutrition. In behavioural context, it relates to the development of competence in a variety of interrelated domains:

i) **Social, cognitive, and emotional development** which refers to the acquisition and refinement of behaviours depending on the basis of culture in which a child is born and reared. It includes understanding and expression of emotions, perception about others, self-awareness, abstract thinking, learning, and reasoning.

ii) Motor skills development relates to the acquisition of enhanced proficiency for a specific motor task. These varies from postural control (ability to hold head up, sit and stand independently) to the coordination of movements (hands working in coordination with the eyes).

GROWTH VS DEVELOPMENT

Goss (1978) has referred to two dimensions of development: the qualitative, which refers to the problem of cellular differentiation and the quantitative one, is growth and size determination. So development is growth coordinated towards the production of the complete organism from immature state to a highly organized, specialized and mature state. Development depends on the maturation and myelination of nervous system. So the sequence is same for all children but the rate may vary. Development ultimately is a product of contribution of Heredity and Environment. Maturity is the measure of functional capacity e.g., the development of motor skills of a child i.e., maturation of the skeletal and muscle systems.

Watson and Lowrey (1962) have described that both growth and development in a normal child parallel each other and any separation would be an artificial one. They restrict the term growth to mean an increase in physical size of the whole or any of its parts which could be therefore measured in terms of inches or centimeters and pounds or kilograms. Development on the other hand indicates an increase in skill and complexity of function. Maturation and differentiation are frequently used as synonyms for development. Used in this sense, it is evident that development is related to growth but is not the same.

GROWTH	DEVELOPMENT
Growth refers to the quantitative change in physical characteristics of an individual such as increase in height, size etc.	Development implies overall change in form and structure qualitatively for enhanced functional skills.
It is a part of developmental process. Development in quantitative aspect is termed as growth.	It is wider and comprehensive term depicting overall change in an individual such as cognitive, emotional, social, acquisition of improved skills etc.
Growth does not continue throughout the life and stops when maturity is attained.	It is progressive and continues throughout the life.
The physical change acquired during growth could be measured directly.	Functional and behavioral changes acquired during development are difficult to measure directly.

PRINCIPLES OF GROWTH AND DEVELOPMENT

CEPHALOCAUDAL AND PROXIMODISTAL DEVELOPMENT

Human development during pre- and postnatal period is not a random process. In fact, it proceeds in a systematic direction as a function of pre-programmed genetic mechanisms. Both, physical and motor development follows two distinct patterns- **cephalocaudal and proximodistal**. The **cephalocaudal refers to the development proceeding from head to toe**. In an embryo, the head is approximately half the total body length. However, by the time of birth, the proportion of the head is reduced to approximately one third of the total body length and becomes further reduced as the limbs and trunk grow increasingly faster. The infant shows voluntary control of the head and shoulders before control of lower limbs**. Proximodistal development proceeds from the centre of the body to the periphery**. For instance, infants acquire control over the muscle of the neck and trunk before coordination of the hands and fingers.

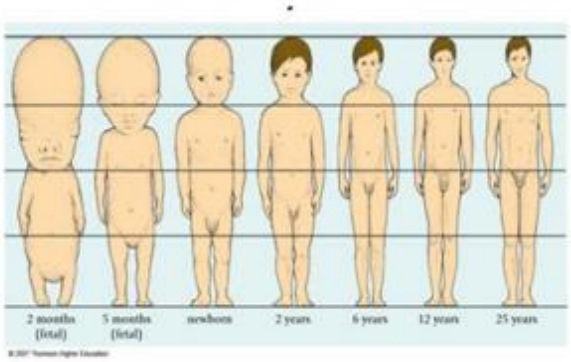


Figure1b: Cephalocaudal development from conception to adulthood

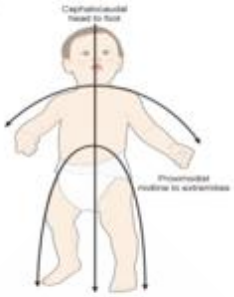


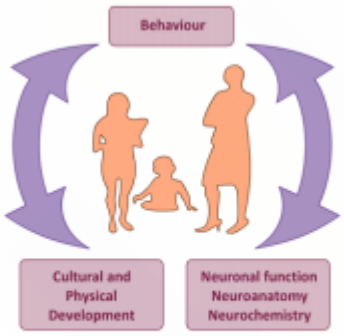
Figure 1a: Cephalocaudal and proximodistal development

Development Proceeds from General to Specific

Initially the infant's movements are very generalized, undirected, and reflexive such as waving arms or move whole body. But later in response to physical and motor development, they become capable of making specific responses or creep toward an object. The infant grasp an object with the whole hand before using only the thumb and forefinger due to development in large muscle movements to more refined (smaller) muscle movements

Development is a continuous process

Development is continuous predictable process which proceeds from conception to the death. It includes the physical, motor, and behavioural development in early life which leads the child to maturity. Changes continues even after maturity has been attained, progressing to senescence and death. It follows a sequential pattern where initial phase of growth and development lays foundation for the next phase. As a child develops, new skills acquired become the basis for further achievement and mastery of skills. For instance, there is a predictable sequence of developments that occur before walking. The infant hold its head up, learn to sit without support, stand by holding on to furniture and then eventually walk alone. Children learn to hold a pencil and crayon before they write or draw.



Development Proceeds at Different Rates

Although each child follows a general pattern and sequence of growth and development, the rates at which individual child reach various developmental stages will be different. There are interspersed periods of great intensity versus plateau with marked individual differences due to age and sex of children. From birth to early adulthood, both stature and weight shows a rapid gain in infancy and early childhood, steady gain during middle childhood, rapid gain during adolescent phase and slow

increase until growth ceases (plateau) with the attainment of adult stature. Body weight however continues to increase into adult life. During early adolescence phase, girls are taller and heavier than boys due to earlier growth spurt. But as the boys attains adolescent growth spurt, they catch-up and eventually suppress girls in body size. Despite this general pattern each child is unique and varies in body dimensions. The rates of development across different domains also may not be uniform within an individual child. Some children will walk at ten months while others walk a few months older at eighteen months of age. A child's intellectual development may progress faster than his emotional or social development. Thus, there is no validity in comparing one child's progress with or against another child.

Development is an interrelated process-genetic, environmental, and behavioural

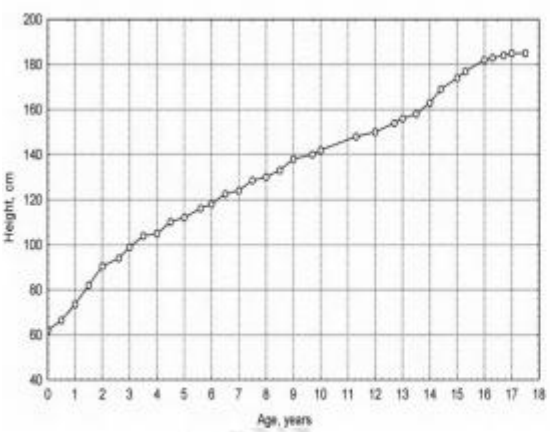
The gene determines the potential of a child to achieve optimal development but is influenced by the sociocultural and physical environment. Maturation, referring to the sequential development of cognitive and motor skills over time, interacts with the child's experiences (learning) in a given environment leading to overall development. A baby cannot feed itself until he or she can sit up and develop the ability to grasp the things between the fingers and thumb. The speech development of a child is affected if the child has difficulties in hearing clearly or if no one talks directly to him or her. Thus, the development of children to their potential requires support and guidance from others in their lives. A child who does not receive love and attention may fail to grow and develop. Abstract thinking and social behaviour during the process of maturation develops according to the peer and family environment they share.

PATTERNS OF HUMAN GROWTH

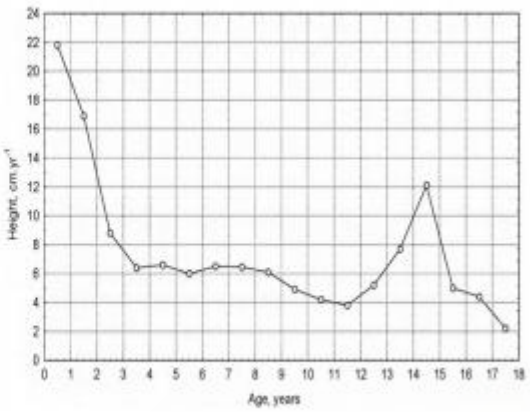
Growth curves

Measurements of an individual taken at specific intervals, when plotted against time provide a graph of progress or total amount of growth achieved. The graph in which the measurements are plotted against the time it was taken is called **distance curve**. It represents the amount of growth achieved at a given moment or at successive time periods. For example, height gained for a given age reflects how far the child has progressed towards adulthood.

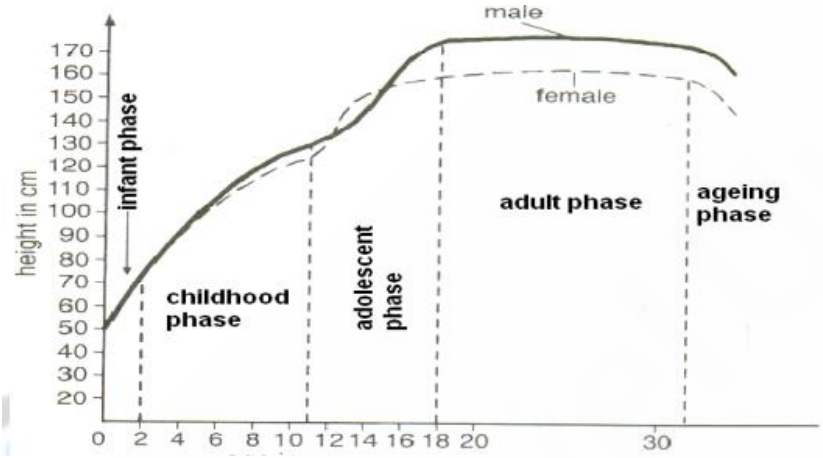
The curve representing the variation in rate of growth with time is known as **velocity curve**. These measurements are ordinarily plotted on a graph with chronological age on horizontal axis to derive growth curves. Sir D"Arcy Wentworth Thompson, a famous British natural scientist and mathematical biologist in his book entitled "On growth and form (1942)", wrote that the distance curve, "showed a continuous succession of varying magnitudes", while the curve of the rate of change of height with time, "shows a succession of varying velocities".



a) Distance curve



b) Velocity curve



Thus, the growth curve has four distinct phases corresponding to relatively rapid growth in infancy, steady growth in childhood, rapid growth during adolescence and very slow growth as the individual approaches adulthood. A rapid growth during childhood known as mid- growth spurt is also observed but is not a universal phenomenon.

GENERAL CURVE

The general curve describes the growth of the body as whole and most of the system of body including skeleton, respiratory, digestive, urinary, and circulatory (heart and blood vessels). The sigmoid or S-shaped curve represents four phases of growth (Malina et al. 2004):

i. Rapid growth in infancy and early childhood
ii. Steady but constant growth during middle childhood
iii. Rapid growth during the adolescence
iv. Slow and eventual cessation of growth after adolescence which continues into third decade of life.

NEURAL CURVE

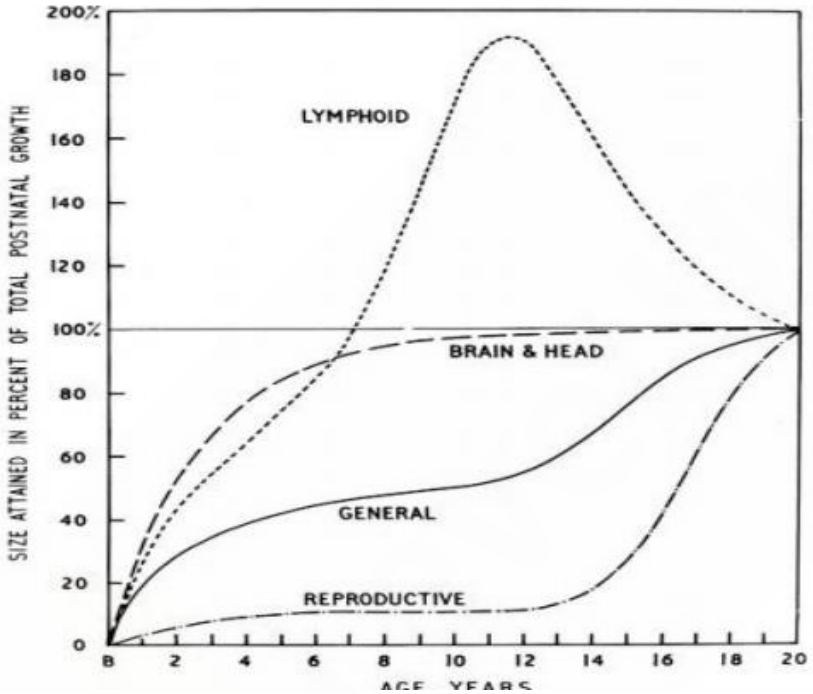
It characterizes the growth of brain, nervous system, and associated structures such as eyes, upper face, and parts of skull. These tissues experience rapid growth in early postnatal life so that, about 95% of the total increment in the size is attained by the age of 7 years. After 7 years the neural tissue show steady gain with slight growth spurt during adolescence.

REPRODUCTIVE CURVE

The reproductive curve illustrate the growth pattern of primary (such as ovaries, uterus etc in females and testes, seminal vesicles etc in male) and secondary sexual characteristics (such as breast in females, larynx in male, pubic hair and others). These tissues show slight growth in infancy followed by latent period during childhood, and rapid growth and maturation during adolescence (Malina et al. 2004)

LYMPHOID CURVE

The lymphatic system which includes thymus, tonsils and spleen and lymph nodes acts as a circulatory system for tissue fluid and develop immunological capacities. The lymphoid curve demonstrates a rapid growth until the early adolescent years. Later, it declines perhaps as a result of the activities of sex hormones during puberty.



A CAPSULE HISTORY OF GROWTH STUDIES

Before the 17th and 18th century mostly the artists started using accurate proportions of the human body in their drawings. The anatomical differences also started to depict in their work with children of normal proportions and growth pathologies. In 1651 physician William Harvey helped establish that the embryo is not a preformed adult, rather that during development the human being passes through a series of embryological stages that are distinct in appearance from the form visible just before and after birth.

Galen (c.AD 130 to c.AD 200) wrote about the appearance of the foetus in the later stages of pregnancy. The first accurate drawings of the foetus were made by Leonardo da Vinci (1452-1519), who dissected a seven month old foetus and stillborn, full-term infants.

Other descriptions of foetal anatomy and physiology followed Leonardo's work, notably by Vesalius in 1555 and Volcher Coiter in 1572. The study of growth after birth began with the concept of infants and children as miniature adults who had to only increase in size during the growing years. By the late 15th century Leonardo's drawings correctly rendered adult and child body proportions.

Albrecht Diirer (1471-1528) devised a method of geometric transformations that he used to accurately render proportions of the human head and face (Bogin, 1991). The first longitudinal study on human growth was made by Count Philibert Gueneau de Montbeillard of France upon his son. He measured the stature of his son every six months from 1759 on the behest of Buffon, who included the measurements and his commentary on them, in a Supplement to his Histoire Naturelle in 1777 (Tanner, 1981). Another 18th century longitudinal study of growth is that of the students of the Carlschule, conducted between the years 1772 and 1794 which included the sons of the nobility and of the bourgeoisie.

In 1835 Lambert Adolphe Quetelet published the first statistically complete study of the growth in height and weight of children. He was first to make use of the concept of 'normal curve' to describe the distribution of his growth measurements. After this a vast number of growth studies were started to be made with the accumulation of dimensional data mostly from the schools, prisons, hospitals and military personals. Along with this several long term longitudinal studies also made its influx between 1927 and 1932 (Tanner 1981). These include the famous Fels Longitudinal Study, at the Fels Research Institute, Yellow Spring; the Bolton-Brush Study at Western Reserve University (Cleveland, Ohio), the Berkeley Growth study, Guidance study and Oakland Growth study at the Institute of Human Development of the University of California (Berkeley), the Child Research Council Study at the University of Colorado (Denver), and the Harvard School of Public Health Growth Study (Boston, Massachusetts) [Roche, 1992].

METHODS OF STUDYING GROWTH

Growth among the children could be studied mainly by two methods**:**

LONGITUDINAL METHOD

1) In this method, the same subject or group of subjects is measured repeatedly from year to year.

2) Individual rates of growth and the timing of specific developmental events could be analyzed with data collected by this method.

3) Data may be analyzed for individual rates of growth and the timing of specific developmental events.

4) A birth to maturity study may take up to 20 years to complete with the help of this methodology.

The principal drawback of the comprehensive longitudinal study is ·

1) The time it takes to complete and the relatively small number of subjects that can usually be followed.

2) Longitudinal studies are by their nature costly and dependent upon the continuous cooperation of the subjects.

It is therefore essential that the highest of accuracy should be maintained in collecting and recording the data and the methods of analysis used should be those appropriate to the methods of study, yielding the maximum and accurate information covering individual growth.

CROSS SECTIONAL METHOD

1) In this method, the subjects are measured only once. Subjects of different ages are measured at a single point of time.

2) This method provides a general description of age-related growth changes.

3) A growth study could be completed within a very short span of time.

4) In a comparative survey of children's growth in different populations, the concern is more with the means and variations of group of children than with the growth patterns of individuals. Therefore the information is usually from cross-sectional studies.

5) 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 these circumstances the relative ease and rapidity with which results may be obtained from a large number of cases makes cross-section methods preferable to longitudinal one.

6) Cross-sectional methods are also obligatory in circumstances where continuity is not possible, e.g. autopsy studies on internal organs (Tanner, 1960).

7) From a cross sectional study, the centiles of distribution could be calculated which are often used as the basis for population standards. A larger number of subjects are necessary for creating effective standards.

There are **limitations** to the usefulness of even large- scale cross-sectional studies.

1) They tell us nothing about individual increments from one year to the next i.e., about individual rate of growth.

2) Though they give us an estimate of the mean rate of growth of a population, they tell us nothing about the variability around the mean. Since this method mixes data of early, average and late maturing children, it results in a mean velocity curve that underestimates the actual velocity of growth of all children during the adolescent spurt.

3) In a clinical context, it is required to compare a given individuals velocity or rate of growth with standards for velocity at his age.

SEQUENTIAL STUDIES

This a method designed to overcome the drawbacks of longitudinal and cross-sectional studies. This method combines the other two i.e. people in cross-sectional sample are tested more than once and the result analysed to determine the differences that show up overtime for different group of subjects. This technique seems to provide more realistic assessment than cross sectional or longitudinal studies.

STAGES OF GROWTH

The Human Life Cycle:

A life cycle is a series of changes in form that an organism undergoes during a course of time. Not all animals have clearly demarcated phases in their life: moreover, among mammals, humans have more such phases than do other species and these phases are well marked by biological transitions.

The Human Life Cycle said to be beginning with fertilization and then **proceed through prenatal growth and development, birth, postnatal growth and development, maturity, senescence and death.** At individual level, old cells die and degrade and the molecular constituents of these dead cells recycled into new cells formed by mitosis. While at the population level, people born, grow, mature, age and die. Fertilization can be marked as the beginning of life and the cycle continue passing through fixed stages ending the cycle at the last stage i.e death. The Human life cycle involves the following stages:

Prenatal stage:

Prenatal stage begins at conception with the union of a man's sperm and a woman's egg to form a single cell embryo. (The process of fusion of sperm and egg to form a zygote is called **fertilization**) Fertilization mark the beginning of prenatal stage of growth which can be further divided into following stages:

1) Embryonic stage/ 1st Trimester (conception - 8th week)

The embryonic stage last from conception to first 8 weeks of pregnancy. The cells of the embryo repeatedly divide as the embryo moves through the fallopian tube embeds itself into the wall of the womb, begins by the end of the third week and is completed during the fourth week of pregnancy. By 5 weeks, development of the brain, spinal cord, and heart is well underway. The heart starts beating is visible by ultrasound almost immediately. By 6 weeks, the heart is pumping the embryo's own blood to his or her brain and body. All four chambers of the heart are present and more than 1 million heartbeats have occurred. The head, as well as the chest and abdominal cavities have formed and the beginnings of the arms and legs are easily seen. The 6-week embryo measures less than ¼ of an inch long from head to rump. Rapid brain development continues with the appearance of the cerebral hemispheres. The embryo reflexively turns away in response to light touch on the face at 7½ weeks. Fingers are beginning to form on the hand.

2) Early Foetal stage / 2nd Trimester (9th - 24th week)

As the early foetal stage started movement of hands, neck turns, and hiccups begin. The heart is nearly fully formed. Girls now have ovaries and boys have testes. **By 10 weeks kidneys begin to produce and release urine**, and intermittent breathing motions begin. All fingers and toes are free and fully formed, and several hundred muscles are present. Experts estimate the 10-week embryo possesses approximately 90% of the 4,500 body parts found in adults. This means that approximately 4,000 permanent body parts are present just eight weeks after conception. Incredibly, this highly complex 10- week embryo weighs about 1/10th of an ounce and measures slightly less than 1¼ inches from head to rum. After 10 weeks, the developing human is called a foetus, which means "little one" or "unborn offspring."

By 11 Thumb sucking and swallowing amniotic fluid begin. Girls' ovaries now contain reproductive cells which will give rise to eggs later in life. Also in girls, the uterus is now present. Fingerprints start forming at 12 weeks while fingernails and toenails begin to grow. Gender differences emerge at 16 weeks when girl foetuses move their jaws more often than boys. A pregnant woman may begin to feel foetal movement at this time.

Around 17 weeks blood cell formation moves to its permanent location inside the bone marrow and the foetus begins storing energy in the form of body fat. By 18 weeks formation of the breathing passages, called the bronchial tree, is complete. By 20 weeks the larynx or voice box begins moving in a way similar to the movement seen during crying after birth. The skin has developed sweat glands and is covered by a greasy white substance called "vernix," which provides protection from the amniotic fluid. At 21 weeks breathing patterns, body movements, and heart rate begin to follow daily cycles called circadian rhythms. By 22 weeks the sense of hearing begins to function and the foetus starts responding to various sounds. The cochlea, the organ of hearing, reaches adult size. All skin layers and structures are complete.

Between 20 and 23 weeks rapid eye movements begin. These eye movements are similar to those seen when children and adults have dreams. By 24 weeks more than 30 million heartbeats have

occurred. The 24-week foetus weighs about 1¼ pounds and measures about 12 inches from head to heel.

3) Late Foetal stage / 3rd Trimester (25th week - birth)

Late foetal stage started by 25th week of pregnancy. By 26 weeks sudden, loud noises may trigger a blink-startle response, which may increase movement, heart rate, and swallowing. The lungs produce a substance necessary for breathing after birth. By 29 weeks, pupils of the eyes react to light. By 34 weeks true alveoli, or "air pocket" cells, begin developing in the lungs. By 37 weeks the foetus has a firm hand grip and the heart has beat more than 50 million times. The 38-week foetus weighs about 6¾ pounds and measures about 19 inches from head to heel. At term, the umbilical cord is typically 20 to 24 inches long. Labor is initiated by the foetus, ideally around 40 weeks, leading to childbirth. At full term birth, newborn babies typically weigh between 6 and 9 pounds and measure between 18 and 21 inches from head to heel.

Summary:
In humans, the prenatal stage, or pregnancy, lasts nine months. In the first trimester, or three-month period, the fertilized ovum multiples into millions of cells. Distinctive cell groupings first represent different kinds of tissues, then give rise to the tissues, the organs, the brain, and the various physiological systems. By the end of the second month, the embryo is about one inch (2.5 cm) long but is recognizably human. Because growth and development are at their most dynamic during this trimester, the embryo is highly susceptible to disruption and disease caused by mutation or environmental factors. Specific stressors, or potentially harmful agents, include the mother's smoking, consuming alcohol, taking drugs, and providing inadequate nutrition.

In the second trimester, the foetus mainly grows longer, from about eight inches (20.3 cm) at the end of the first month of this trimester to about 14 inches (35.6 cm), or three-quarters the length of an average newborn. The third trimester involves rapid weight growth and organ development. During the final month, the lungs develop and most reflexes become fully coordinated.

The foetus's wide range of movement includes the ability to grasp and to respond to light, sound, and touch. This trimester culminates in birth, the profoundly stressful transition from the intrauterine environment to the external environment. Half of all neonatal deaths occur during the first 24 hours. Most of these deaths are caused by low birth weight (less than 5.5 lbs, or 2.5 kg), which is generally linked to one or a combination of multiple stressors, such as maternal malnutrition, smoking, and excessive alcohol consumption. Because individuals of low socioeconomic status tend to be exposed to environmental stresses, their children are prone to low birth weights and early deaths. And a poor intrauterine environment predisposes the person to developing specific diseases later in life.

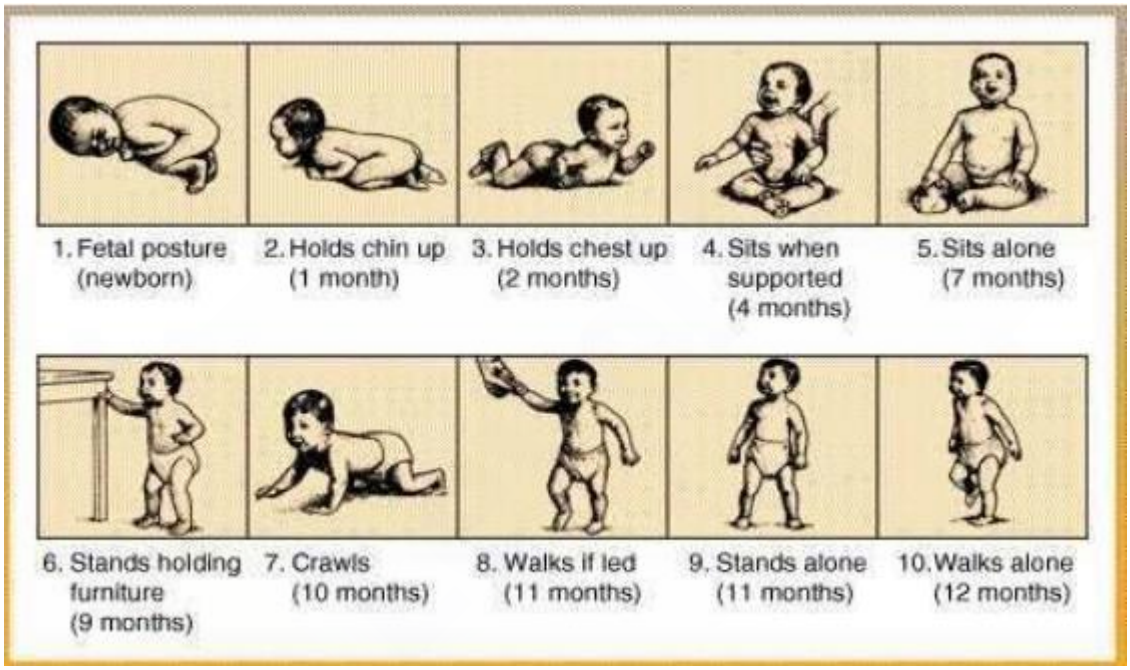
POSTNATAL GROWTH

The 28 days post birth delineated by rapid growth and adaptation to extra uterine environment. The new born is detached from the mother's placenta and now relies on their own circulatory, digestive and excretory system. They maintain their body temperature within very narrow limit. Inadequate growth and development during prenatal period disposes the new born to vulnerability especially for the duration of 24 days after birth and is the pioneer factor contributing to high neonatal mortality rate.

INFANCY

Infancy is defined as the period during which nursing takes place, typically lasting about four years in humans. The first year is characterized by rapid physical growth. A normal baby doubles its birth weight in six months and triples it in a year. During that time, there is great expansion of the head and chest, thus permitting development of the brain, heart, and lungs, the organs most vital to survival. The bones, which are relatively soft at birth, begin to harden, and the fontanelles, the soft parts of the newborn skull, begin to calcify, the small one at the back of the head at about 3 months, the larger one in front at varying ages up to 18 months.

Brain weight also increases rapidly during infancy: by the end of the second year, the brain has already reached 75% of its adult weight. (Bogin 2001). The development of the skeleton, musculature and the nervous system accounts for motor and cognitive advancements. The human brain grows more rapidly during infancy than any other tissue or organ of the body. Rapid motor skills development is mostly intended for the development of the upright posture and independent locomotion. The gradual attainment of control over head, upper trunk and upper extremities is allied with accomplishment of sitting posture and proficiency in walking skills by the age of 4 years.



Emergence of deciduous dentition allows the infants to switch from dependence on breast/infant food feeding to eating appropriate weaning foods. Infants will erupt five deciduous teeth in each quadrant of their mouth. This is noteworthy that deciduous teeth of boys emerge about one month earlier than girls, as in other aspects of physical growth and maturation girls are, on an average ahead of boys.

CHILDHOOD

Early childhood

As the childhood approach the rate of growth decreases or slows down. The constraints of immature dentition, small digestive system, and rapid growth of brain among children necessitate specially prepared foods. Susceptibility to disease and procurement of food incline them to be dependent on elder people. The neurological development enhances psycho-motor skills and by the end of this phase, child is able to comprehend language accompanied by social, physical and cultural norms. Learning ability which was launched in the 1st year becomes faster as the child is exposed to environment. (Tanner, 1962)

Teeth eruption started in this stage of growth, and it was also observed that boys are taller than girls with respect to physical growth. Attention span is short at this stage.

Middle Childhood

This growth stage in human cycle is supposed to be most stable period characterized by differential rate of growth in different body parts and changes in body proportion by the age of 9 years. Physical growth proceeded in two directions during the childhood and prior stages of growth which are with the acquisition of proficiency in locomotion, child is able to walk like adults efficiently by the age of 7 years.

Replacement of milk teeth by permanent teeth is almost complete, with the exception of the 2nd molars.

Late Childhood

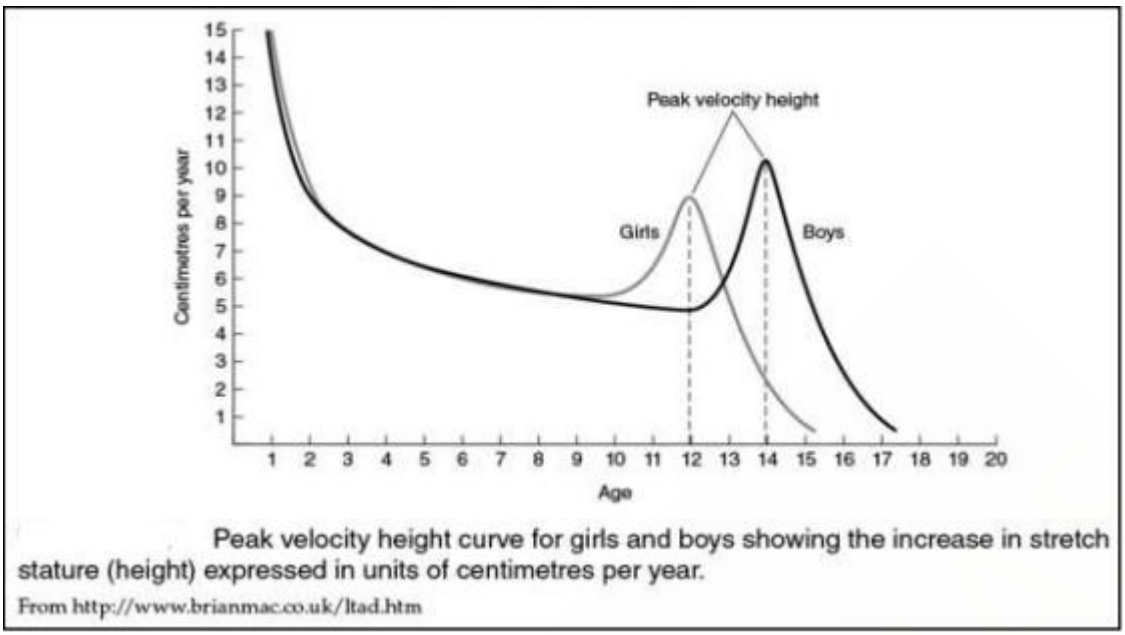
Late childhood is influenced by growth of sex hormones. It can be called as pre-pubertal stage in which linear rapid growth took place. It marks the beginning of adolescent growth spurt and sexual dimorphism in body size and proportion during pre-pubertal stage. Understanding of abstract concepts, enhanced reading, writing, and speech skills were also at its best. All these indicators show that the physically dependent child is moving on to independence.

ADOLESCENCE

During the teen years, adolescents experience changes in their physical development at a rate of speed unparalleled since infancy. The beginning of biological growth and development during adolescence is signified by the onset of puberty, which is often defined as the physical transformation of a child into an adult. A myriad of biological changes occurs during puberty including sexual maturation, increases in height and weight, completion of skeletal growth accompanied by a marked increase in skeletal mass, and changes in body composition. The succession of these events during puberty is consistent among adolescents; however, there may be a great deal of deviation in the age of onset, duration, and tempo of these events between and within individuals. For this reason, adolescents of the same chronological age can vary greatly in physical appearance. This has direct relevance for the nutrition requirements of adolescents. A 13-year-old male who has nearly completed the linear growth spurt associated with puberty and has experienced significant muscular development will have remarkably different energy and nutrient needs than those of a 13-year-old male who has not yet experienced puberty.

Consequently, sexual maturation should be used to assess the extent of biological growth and development and the individual nutritional needs of adolescents in place of chronological age. The maturation is signalled by a rapid acceleration in the growth velocity of virtually all skeletal tissues- the adolescent growth spurt. An increase in growth velocity marks the commencement of adolescent spurt. The growth rate which eventually reaches a maximum, articulated as a peak height velocity (PHV) and gradually decline. The rate of growth and age at PHV indicate the intensity and timing of adolescent spurt respectively. The rise to PHV is relatively slower than after peak. Age at peak height velocity is an individual characteristic and is commonly used as maturity indicator.

The boys gain their adolescent growth spurt on an average between 12.5 and 15.5 years of age with PHV between ages 13.5-14.5 years. Girls enter puberty 2 years earlier than boys and attain the PHV between ages 11.5-12.5 years.



Peak velocity height curve for girls and boys showing the increase in stretch stature (height) expressed in units of centimetres per year.

From http://www.brianmac.co.uk/ltad.htm

Adolescent in human life cycle is characterize by the pubertal growth spurt in height and weight ; completion of permanent teeth eruption(except third molar, which erupts between 17 to 25 years); development of secondary sexual traits, including sex-specific alterations to fat and muscle distribution; psychological and behavioral changes related to sexual and social maturation.

Sexual maturation is the most important part of adolescent which include following characteristics:

GIRLS

Breast Development	Stage	Pubic Hair Growth
Prepubertal; nipple elevation only	1	Prepubertal; no pubic hair
Small, raised breast bud	2	Sparse growth of hair along labia
General enlargement of raising of breast and areola	3	Pigmentation, coarsening and curling, with an increase in amount
Further enlargement with projection of areola and nipple as secondary mound	4	Hair resembles adult type, but not spread to medial thighs
Mature, adult contour, with areola in same contour as breast, and only nipple projecting	5	Adult type and quantity, spread to medial thighs

BOYS

Genital Development	Stage	Pubic Hair Growth
Prepubertal; no change in size or proportion of testes, scrotum and penis from early childhood	1	Prepubertal; no pubic hair
Enlargement of scrotum and testes; reddening and change in texture in skin of scrotum; little or no penis enlargement	2	Sparse growth of hair at base of penis
Increase first in length then width of penis; growth of testes and scrotum	3	Darkening, coarsening and curling, increase in amount
Enlargement of penis with growth in breadth and development of glands; further growth of testes and scrotum, darkening of scrotal skin	4	Hair resembles adult type, but not spread to medial thighs
Adult size and shape genitalia	5	Adult type and quantity, spread to medial thighs

Source: Data from Tanner JM. Growth at adolescence. Oxford: Blackwell Scientific Publications, 1962.

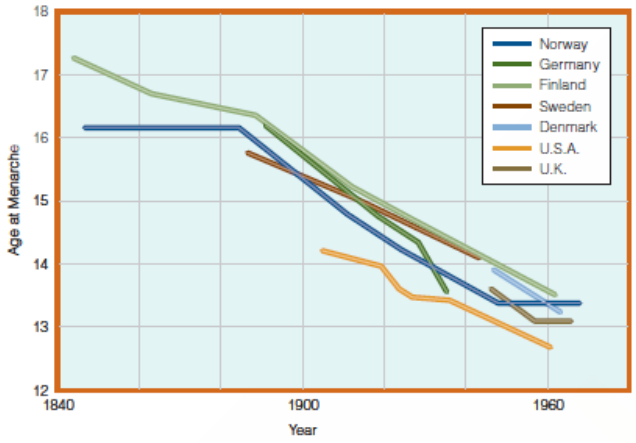
In a study by Kant et. al. it was found that puberty appears to set in early among the Indian boys but full maturation seems to take longer time than the boys of Western countries. Their study was based on Jabalpur boys.

For Indian boys median age for development of pubertal sign is 14 years. The onset of puberty is found late in tribal boys.

The age of menarche varies considerably in different parts of the world and it is influenced by socio-economic status, nutritional status, besides genetic component.

The secular trend in age of menarche in Western nations.

From James W. Wood, Dynamics of Human Reproduction (New York: Aldine de Gruyter, 1994); original redrawn from P. B. Eveleth and J. M. Tanner, Worldwide Variation in Human Growth (New York: Cambridge University Press, 1976).



A.M. Tripathi in his study of age of menarche of girls of various Indian states found that lowest age is in the girls of Delhi (11.20) followed by Calcutta (12.50) and UP (12.80). the highest age of menarche was found to be in Gujarat (14.80).

ADULTHOOD /MATURITY/PRIME

Just as it is difficult to determine precisely when adolescence begins and ends, determining exactly when adulthood commences proves elusive. Adulthood is, for most people, the time of peak physical capacity. The body reaches full height by the late teens, and physical strength increases into the late 20s and early 30s (Whitbourne, 2001). The attainment of adult stature and sexual maturation are the indication of transition from adolescence to adulthood. Height stops as the long bones of the body like femur lose their ability to increase in length. (Bogin 2001). A process called epiphyseal union in which growing end of the bone fuses with the diaphysis, the shaft of the bone under the stimulation of gonadal hormones has been take place to attain skeletal maturation. While the children without gonads or whose gonads are not functional never experience epiphyseal union, but they do stop growing, signify that the change in the sensitivity to growth stimuli of cartilage and bone tissue in the growth plate region leads to the loss of hyperplastic growth potentials in cells.

This phase of human life cycle is considered as the child bearing phase of life. Also, in context of sexual maturation, the production of viable spermatozoa in boys and oocytes in girls is achieved during adolescence but these events mark only the early stages, not the completion of reproductive maturation.

Thus, transition to adulthood is marked by dramatic events such as the cessation of height and attainment of full reproductive maturity. However, the most striking feature of the adulthood stage is its stability, or homeostasis and its resistance to pathological influences, such as infectious disease and physiological stress.

SENESCENCE

Senescence is also known as declining stage or negative growth. Senescence is all those manifestations in structure and function of various organs of the body which are of declining and deteriorating nature which take place during the later period of life. In humans, ageing takes the form of a morphological and functional involution as a progressive and irreversible change, which affects most of the organs and leads to a gradual decline in all the activities of the individual. Although ageing is a continuous process of change throughout the life span of an individual but with increasing age organs weaken fractionally. All individuals follow the same human cycle i.e., growth, reproductive maturity, senescence and death.

The pattern of activity from birth to death roughly follows the path of a parabola. In ontogenesis, most of the properties of man exhibit progressive changes in youth and regressive ones in old age. However, the latter are not reversal to the previous conditions but an emergence of the new qualities; hence they represent a development, but a regressive one (Nagele, 1981). Following are important points regarding senescence: At the age of 60+ there is a decrease in stature because of compression of vertebral disc- memory loss can occur, and reasoning ability can diminish- mineralization increases; bones become brittle and more susceptible to fracture- decrease in functional ability- teeth loosen- decrease in water content- immune system becomes weaker- muscles deteriorate.

WHY STUDY THESE PHENOMENA?

Human variability

An array of environmental factors (such as nutrition, disease, physical activity, and others) interacts with the genetic potential of an individual during the years of growth and maturation. This results into a wide range of inter- and intra-population variation through differential rate of growth of particular parts of the body relative to others. Understanding these biological variations in terms of origin and distribution among different populations underlie the significance of conceptual knowledge of these phenomena.

Health status

The assessment of growth and maturity at periodic interval monitors the health status of a child and identifies deviation from normal growth if any. When compared with the healthy children of same age and sex, it indicates the overall health and nutritional circumstances in a community. This approach is often used in the context of nutritional status and general health surveys.

Progress

The measurement of children at specific intervals of time provides an estimate for the rate of growth and maturation. It estimates the level of biological maturity for the child's chronological age- whether early (advanced), late (delayed) or average (appropriate). A child who grows 5cm over a period of one year has a growth rate of 5cm/year. The measurements over time on the same individual trace the constancy in the growth indicators from childhood through adolescence to adulthood. Several studies have predicted the tendency of overweight adolescent to become overweight adult by measuring or observing similar individual over period of time. However, several factors may influence the prediction which includes interval between measurements, age at first observation, timing and tempo of adolescent spurt, significant environmental change, and measurement variability (Malina et al. 2004).

Physical activity

Regular participation in physical activity is presumably necessary for optimal growth and maturation of a child. However, to evaluate and recognize the potential effect of physical activity, an understanding of normal process of growth and maturation is important. Also, the performance of an individual is influenced by the growth and maturity status. Among boys of the same age, those who are biologically mature tend to be taller, heavier, and stronger than boys who have not matured. Muscular strength is related to body size, and such provide an advantage to athletes in variety of sports such as gymnastics, divers etc.

Evolution

Over a period of time, human have evolved morphologically and physiologically to adapt to the surrounding environment. The evolution of morphological characters is the consequence of alternations in the inherited pattern of human growth and development. Thus, the study of growth is crucial in elucidating the mechanisms of evolution.

CHRONOLOGICAL AND BIOLOGICAL AGE

Human body two types of age – chronological age and biological age. Chronological age is the one we all are familiar with, as the number of years denoted by Earth's revolutions around the sun. It is the current age in years, calculated from the birth date. Chronological age is the actual number of years a person has lived in years, months, days, or a combination of all of these; for example 15 years, 3 months, and 12 days. Biological age, on the other hand, represents the biological status of maturity referring to how old a person seems to be. It is an individual's development based on certain biomarkers - a recordable molecular or cellular event. Biological age, also called physiological age, determines the extent of body functioning relative to actual calendar age. For example, one may have a calendar or chronological age of 65, but because of healthy and active lifestyle, avoiding longevity threats like consumption of tobacco or subjection to obesity, that person is physiologically more similar to someone with a chronological age of 55. In that case, his/her biological age would, therefore, be 55.

So, the biological age is a measure of how time and lifestyle have affected the organs and cells compared to other people of the same chronological age. Experts consider telomeres (the protective ends of chromosomes) while calculating the age difference between the chronological and biological age. Telomeres prevent chromosomal ends from deteriorating or fusing with a neighbouring chromosome, affecting the tempo of ageing of cells. It implies that greater the chronological age, the shorter the total length of telomeres will be. However, maintaining a healthy lifestyle, inclusive of a healthy diet and regular exercise, may also maintain telomere length.

Factors determining Biological Age

There exist several factors that can determine/ influence the biological age of an individual, but none of these are definitive or accurate, rather that would give years on an average life expectancy.

- **Lifestyle**

Healthy living habits have significant impact on longevity and extended biological age. These majorly include exercise/physical activeness, eating/dietary habits, stress levels, alcohol/tobacco consumption, level of education, amount of sleep, sexual/romantic relationships. Enough of physical activity, dietary pattern constituting more of nutrient-rich content and less of fatty entities, less or no stress and keeping it away from drinking and smoking tend to influence longevity in positive terms.

Decreased biological age has been found associated with lower educational background and lesser hours of sleep.

• **Heredity** Genetic predisposition/vulnerabilities are another major factor responsible for influencing biological age. Heredity/gene pool contributes to increased biological age that has nothing to do with lifestyle habits. Just as the way specific diseases run in families, longevity also does. If a person has family members who have lived longer than 96 years, chances are that the person would also lead a longer life - even if his/her lifestyle patterns are less than healthy.

• **Habitat/ geographical nativity** Another important factor influencing biological age is the place where you live. There lies no secret in the fact that the environment and culture one lives in is directly linked to the person's healthy living.

SOMATOTYPING

Somatotype refers to a quantified expression and description of the present morphological conformation or physique of a person and the process of appraising and defining it is known as somatotyping.

Somatotypical studies have contributed to our understanding of diversity of human builds and been applied to specific diseases, osteoporosis, relations between musculoskeletal system and ageing, exercise programs for individual athletes, and potentials of athletes. In fact, Sheldon developed the idea of somatotype in his search to find the relationship between human physique and behaviour.

Somatotypes are affected by environmental factors such as occupation, nutrition, housing, medical support, and lack of primary health medicine. They are important in our daily life for their useful application in industries of electronics and clothes as well as anthropology, bio-engineering, medicine, and sports. Especially, in the area of physical therapy, somatotype studies related to thermal and integumentary physical therapy, musculoskeletal system exercise treatment, obesity control physical therapy, and sports physical therapy were diligently pursued.

The foundations of the classification of human physique started in the 5th century BC, Hippocrates, a Greek doctor divided somatotypes into habitus phthisicus and habitus apoplecticus. The former refers to long and thin body builds which are vulnerable to tuberculosis and the latter is short and fat body builds which are more exposed to blood vessel diseases and strokes.

Viola's Method (1921)

Viola, an Italian physician proposed a classification of biotype (physique) based on a comprehensive system of anthropometric measurements. He differentiated four morphological types:

1) Longytype: The longytype had long limbs relative to their trunk volume, large thorax relative to their abdomen, a large transverse diameter relative to anterior posterior diameter.

2) Brachitype: The brachitype was characterised by massiveness and robustness of body, the reverse of longytype. They had short limb relative to trunk, short transverse diameter relative to the antero-posterior diameter, short thorax relative to the abdomen.

3) Normatype: The normatypes were in between longitype and brachytype characterised by normally proportional limbs versus trunk, thorax versus abdomen, transverse versus antero-posterior widths.

4) Mixed: Mixed type shows disproportion in human body. It lacks uniformity in the physique.

The four indices failed to agree amongst themselves, one placing the individual in one category and another elsewhere. This is a subjective method and hence not used any more.

Kretschmer's Method

Kretschmer was a German psychiatrist. His system of classification relied entirely on anthroposcopic inspection. He illustrated four physical and psychic types derived from his clinical observations and minimum measurements:

1) Pyknic: The pyknic was broad, round and fat, sturdy and stocky.

2) Athletic: The athletic was heavily muscled with large thorax and shoulders and narrow hips.

3) Leptosomic: The asthenic was long, thin, and linear.

4) Dysplastic: It denoted the incompatible mixture of different types in different parts of the body.

Criticism

This system is now entirely outdated.

a) It supposed that it was possible to classify people into separate discrete types. This assumption was widespread up to about the 1930's. The later practitioners had to admit that most people fell in between the established and obviously fairly extreme types.

b) It had also been criticized of limited sampling, scanty measurements, lack of indices, subjective estimates, and failure to classify data according to age, sex, and social status.

Sheldon's Method

William Herbert Sheldon (1898-1977) was an American psychologist and physician. He introduced the concept and word 'somatotype' in 'The Varieties of Human Physique' (1940). He defined somatotype as 'quantification of three primary components determining the morphological structure of an individual expressed as a series of three numerals, the first referring to endomorphy, the second to mesomorphy, and the third to ectomorphy'. The conceptual approach is based on the premise that continuous variation occurs in the distribution of physique and thus the variation is related to differential contributions of three specific components. Sheldon divided body component into 5 areas:

i) Head, face, and neck

ii) Thoracic trunk

iii) Arms, shoulders, and hands

iv) Abdominal trunk

v) Legs and Feet

The extreme somatotypes are:

1) **Endomorphy**

a) Various parts of the body are soft and round

b) Head is round

c) Abdomen is fat

d) Arms and legs are weak and fatty

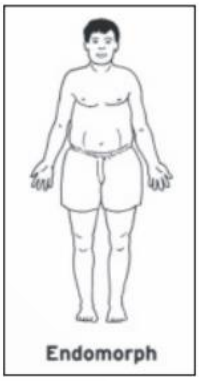
e) Upper arms and thighs are fatty

f) Wrist and ankles are splendidly built

g) Less linearity and less muscularity

h) More fat deposition

i) Somatotype rating is 7-1-1



2) Mesomorphy

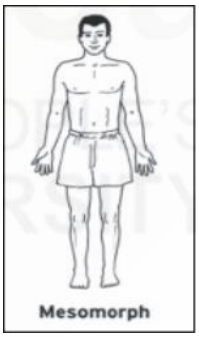
a) Bony and Muscular

b) Heavy, coarse physique with rectangular contour

c) Their head is massive and cubical d) Shoulder and chest broad

e) Less fat and less linearity

f) Somatotype rating is 1-7-1



3) Ectomorphy

a) Typical characteristic is linearity

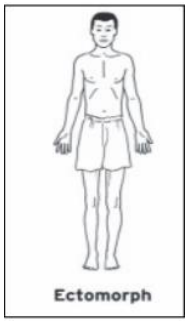
b) Face is thin

c) Forehead is high

d) Chin is receding e) Chest and abdomen is thin and narrow

f) Less fat and less muscularity

g) Somatotype rating is 1-1-7



Each component of physique is assessed individually. Rating are based on a 7- point scale, with 1 representing the least expression, 4 representing moderate expression and 7 representing the fullest expression of that particular component being assessed. The rating of each component determines the somatotype which is expressed by three numerals to sum of no less than 9 and no more than 12.

Criticism

i) The somatotype changes: Sheldon stated that the somatotype is a trajectory along which an individual under average nutritional condition and absence of major illness is destined to travel. He used the word 'morphophenotype' to refer to the present physique and 'morphogenetic' to refer to genetically determined physique. He maintained that somatotype do not change throughout because it does not change significantly for any measurements except where the fat is deposited.

ii) Somatotype is not objective. It was developed on white males of limited age range.

iii) Ignores role of environment on human physique.

iv) Overall body, size and shape is ignored.

Heath Carter Method:

Heath (1963) described certain limitations in Sheldon's method and suggested the following modifications to overcome them:

i) Opening the component rating scales to accommodate a broader range of variation by replacing the arbitrary 7-point scale with a rating scale of equal appearing intervals. Beginning theoretically with zero (in practical beginning with one half) and having no arbitrary end point.

ii) Eliminated the unjustified restrictions of sums of components to between 9 to 12.

iii) Construct a table that preserves a logical linear relationship between somatotype rating and HWRs.

iv) Adopt a single table of HWRs (Height-Weight Ratios) and somatotype suitable for both sexes at all ages.

Heath and Carter combined both photoscopic and anthropometric procedures to estimate somatotype. Somatotype is defined as representing the individual's "present morphological conformation; expressed in a three numeral rating of primary components of physique that identify individual features of morphology and body composition". In practice, the Heath-Carter method of somatotyping is primarily in its anthropometric form. Anthropometry is more objective and obtaining standardised somatotype photographs is difficult and costly.

The somatotype components and the dimensions used in the Heath-Carter anthropometric protocol to derive each component are as follows:

1) **Endomorphy** (1/2-16th scale): The first component, endomorphy, is described from the sum of three skinfolds namely the triceps, subscapular, and supraspinale. It refers to relative fatness of a physique.

2) **Mesomorphy** (up to 17th scale): The second component, mesomorphy, refers to relative musculoskeletal development adjusted for stature. It is described as expressing fat-free mass relative to stature. Mesomorphy is derived from biepicondylar breadths of the humerus and femur, flexed-arm circumference corrected for the thickness of triceps skinfold and calf circumference corrected for the thickness of the medial calf skinfold corrected of the thickness of medial calf skinfold. Correcting the circumferences is simply a matter of subtracting the skinfold thickness from circumference. These four measurements are then adjusted for stature.

3) **Ectomorphy** (up to 9th scale): The third component, ectomorphy, is the relative linearity of build. It is based on the height divided by cube root of weight.

Advantages:

i) Objective

ii) Can be used for both male and female

iii) Measures present somatotype.

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