Fundamentals of Human Growth
“Education is a liberating force, and in our age it is also a democratising force, cutting across the barriers of caste and class, smoothing out inequalities imposed by birth and other circumstances.”

— Indira Gandhi
Block 1

FUNDAMENTALS OF HUMAN GROWTH

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Growth and development are processes intrinsic to all living organisms. Since both these processes proceed hand in hand, one may tend to consider them a single biological phenomenon. However, these are not identical but qualitatively different processes. Growth broadly refers to increase in overall size of the body and specific body parts. Development commonly denotes increase in complexity and functional ability. The process of growth begins with the fertilized ovum and continues up to adulthood when an individual attains his/her adult size, shape and maturity. Thus, growth and development (including maturation) are fundamental processes that shape an individual's progression from birth to adulthood. Some biological changes continue even beyond adult life till death of an individual. The whole process of human growth passes through various phases namely: prenatal phase, infancy, childhood, adolescence, adulthood and senescence.

Though scientific investigations of human growth probably started sometime in the 18th century, but the idea of growth perhaps goes back to prehistoric or early historic period where rock paintings and sculptures showed humans in different ages and sex. In the subsequent 19th century studies on human growth continued under motivation from political, racial, medical and scientific considerations. The 20th century witnessed significant advancements in the methodologies, treatment and interpretation of growth data and several long duration interdisciplinary longitudinal growth studies were carried out that provided baseline information about child growth.

The anthropological approach to human growth and development integrates research about people from all parts of the world, from past as well as contemporary cultures. The study of growth and development is very important in biology as it also throws light on the mechanism of evolution. The complex process of human growth and development is mainly regulated in predetermined trajectories by the genetic potential of an individual. Though growth in body size is limited by hereditary factors, it is also influenced by extraneous factors such as nutrition, ethnicity, environment, climatic conditions, disease, etc. An individual's growth may slow down during childhood under the influence of environmental insults such as disease and poor nutrition. However, upon improvement in conditions, one is able to return to or nearly approach one's regular course of growth. Thus, we can also say that growth, development and maturation are integrated and these are largely maintained by a constant interaction between genes, hormones, nutrients and some other factors.

To study the process of growth we make observations through measurements, which may be linear (e.g., height, sitting height, head breadth), circumferential (e.g., head circumference, mid-upper arm circumference) or pondreal (e.g., weight). These measurements can be plotted in the form of graphs to obtain two types of curves namely the distance curve and the velocity curve. The former indicates the overall growth at some point of time while the latter denotes the amount gained in a unit of time or the rate of growth. There are several methods of studying human growth, such as cross-sectional (in which the individuals are measured only once), longitudinal (wherein individuals are measured more than once), and mixed longitudinal (wherein some individuals get included and some leave an ongoing longitudinal study).

The Units of this block will focus on the fundamentals of human growth and development, including the basic concepts, historical development, methods and techniques of studying growth, secular trends and the factors affecting human growth and development.
UNIT 1 INTRODUCING HUMAN GROWTH AND DEVELOPMENT

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1.1 Introduction
1.2 Defining Growth and Development
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Learning Objectives
Once you have read this unit, you will understand:

➢ the terms growth and development;
➢ the historical development in this field;
➢ how every study has contributed our today’s knowledge; and
➢ the aims and scope of human growth and development.

1.1 INTRODUCTION

All living things are mortal. Reproduction is essential for those organisms that die, yet need to replicate; and to achieve this growth and development becomes mandatory. In fact growth is one of the important hallmarks of a large majority of living organisms. Human beings reproduce sexually which means they require biological material from both their parents. They undergo a long process of growth and development to look something like their parents.

1.2 DEFINING GROWTH AND DEVELOPMENT

Every human being begins his/her life as a single cell - the fertilized ovum. The cell undergoes division, growth, differentiation and development through the stages of embryo, fetus, infant, child and adult. This process goes on under the influence of environment and genetic traits from the parents. As we learnt in the earlier units, it is clear that although growth and development may occur simultaneously both are distinct biological processes. Growth and development is the progression by which human advances biologically from conception to death.

In common terms growth refers to an increase in size of the body as a whole or that of a specific body part. For example when we talk of children growing, it means that they are becoming taller and heavier and their organs are increasing in size. Development signifies a broader concept- the differentiation and specialization of various tissues and body parts of embryo and fetus. Development also means increased complexity in thought, behavior, skill, or even function.
1.3 HISTORICAL BACKGROUND

The wealth of knowledge in human growth and development has not come with ease rather it underwent laborious, prolonged and hazardous history of intellectual development. The scientific study of human growth probably began in the late eighteenth century with the oldest published record of the growth of a child by Count Philibert de Mountbeillard during the years 1759-1777 that was published in a supplement to the *Histoire Naturelle* by Buffon. However, vague idea of growth could be traced to the prehistory and early historic period where the rock paintings or the stone sculptures depicted humans in different ages and sex. Earliest written records on human growth and development come from Mesopotamia about 3500 years before present. Inscriptions communicate the act of fertilization, full term and premature birth and nine month pregnancy. Apprehension regarding low birth weight or prematurity, birth defects and twin births are also evidenced. Sumerians categorized the postnatal life into stages similar to modern concept of infancy, childhood, youth, adulthood and senescence. Though some art portray differences between size of a child and adult but there appears no direct substantiation of body measurement. Incidentally disproportional taller males as higher status than females as lower status are also portrayed in art. Positive relationship between health, social status and stature is there in several texts. All these reflect that both in Sumerian art and in life, there exists relationship between growth and biological conditions. Ancient Egyptian, Chinese, Hindu, Greek and Mesoamerican civilizations pursue many of these Sumerian traditions. Written records and art work indicating the earliest concern in the biology of children was prime interest with preservation of life. Greek, Roman and Arab physicians recommend regimes of physical activity, education and diet promising health of children. All this meant that all human societies must converge on basic strategies for the care and feeding of their young. Egyptians and early Hindu, the early civilizations showed cautious concern for measurement of children and youth’s body. Egyptians used grid system for body proportions while Chinese and early Jewish traditions laid stress on spiritual aspects of human development in their concern for young. Ancient societies showed concern for stages of life which even today is very popular.

Considering the Latin West and the Renaissance scenario, three dimensional sculptures depicting the body dimensions of infants and children are portrayed with fair precision in Egyptian, Greek and Roman artwork. On observation of this art it strikes that infancy, childhood, youth and other ‘seven stages of life’ were pertinent to its biology and behaviour. The philosophy that there are seven stages of life continued following the collapse of Roman empire but with a difference; there appears to be shift in the status accorded to children and youths. Medieval physicians, clerks and artist believed that children were miniature adult; the growth and development of infant to adulthood required only an increase in size and maturity during growing years.

During medieval period there was no scientific approach to human growth and development. Renaissance period witnessed the resurgence of classical Greek concept of dynamics of growth though it never could find place with Greek or Romans. It was Leonardo da Vinci’s idea that new studies in human body growth and development from conception onwards needs to be initiated. He commenced his study of a seven month fetus, the placenta and still born full term infants. Landmark event of human growth and development was Zerbis in 1502 publishing the anatomical difference between child and adult, followed later by several medical and scientific studies. Leonardo’s scientific work was depicted in his drawings of child and adult having right proportion. He infact developed the rule for drawing human proportion using Vitruvius, a first century architect. Diirur, a German, developed a technique using geometric transformations for deducing proportion of human head and face.
This enabled him to draw human variation in any size and proportion; in fact he drew infants, children, women and men. Post-Renaissance, after 1600, painters in fact depicted children with normal proportion and also with growth pathologies. Biological control of normal and pathological growth was not known at that time. It is not understood how scientists and physicians of that time considered different types of dwarfism.

As far as embryonic and fetal development is concerned much has been written about human growth and development prior to birth by Ancient, Classical and Medieval scholars. Though some information is based on actual observation of human and non-human fetus but mostly is result of imagination and myth. From fertilized ovum to the birth, the entire process is so contrary to the expectations based on our understanding of child growth after birth that earlier scholars were convinced that it actually occurred. William Harvey in 1951 proved that embryo is not preformed adult; rather there are series of embryological stages that are distinct in appearance from what we see just before or after birth. Leonardo da Vinci is credited with the first ever accurate drawing of the fetus and followed by descriptions of fetal anatomy and physiology by Vesalius in 1555 and Volcher Coiter in 1572.

The descriptions of fetal anatomy continued during the seventeenth and eighteenth century with most of the information based on last trimester of pregnancy. At this stage the fetus distinctly gives human appearance. Although now these studies are quite informative but they provided no answer to the physical changes that took place earlier in prenatal life. It was in 1799 that S. T. Sommerring published drawings of human embryo and fetus from fourth week post fertilization to fifth month which vividly showed that embryo is not a miniature adult. Karl Ernst Baer in 1829 described the germ layers—endoderm giving rise to internal organs, mesoderm forming the skeleton and muscles and ectoderm develops skin and teeth. Though Baer’s removed many misconceptions, yet it was not until twentieth century that an understanding was attained of the highly complex process occurring during prenatal growth.

Eighteenth Century Contributions

Longitudinal studies

The effect of early life events affecting later development was another interest post Renaissance. 1700s saw physicians interest in following the birth weight of the child vis-a-vis child’s health. Pre- and neonatal influences, on later development are interest of today’s researchers. This directed towards longitudinal studies which facilitated to study the relationship between early influences and its effect on growth. In this approach, same individual is examined at least twice with some time gap. Preceding the longitudinal study, it was cross-sectional study which was common practice and in which the individual is measured only once. The merit of cross-sectional study is that it is faster and can be completed in short period of time, but has a demerit that the dynamics of the growth cannot be studied.

The Count Phillibert Gueneau du Montbeillard of France holds historical importance. He measured the height of his son since birth every six months till he was 18 years. George-Louie Lec1rec de Buffon included the measurements and his commentary on them which was the most famous study and also considered as first longitudinal study. The growth in height of the boy both in terms of attained stature by age and rate of growth were well documented graphically. The data was converted to modern units from obsolete French units by Scammon in 1922. The result, distance curve and velocity curve, became an integral part of growth studies. Another landmark eighteenth century longitudinal study was of Carlshule’s students, conducted between 1772 and 1794.
Political perception

Political and legal decision concerning the treatment of children came into picture for the first time in nineteenth century growth research. There was lot of influx of rural to urban migrants with the growth of European cities during eighteenth century resulting in dislocation from traditional rural family social organization in an urban setup. Subsequently, there was an increase in number of infants and children in the community-care and hospitals; and the growth and health of these abandoned children was extremely poor resulting in their death. Cadogan’s Essay echoed a general apprehension for infant’s health in England resulting a law being passed ensuing the working of foundling homes in 1767. Rousseau in his book Emile in 1762 advocated ‘return to nature’ including breast feeding of infants by their own mother since artificial feeding lead to many complexities due to hygiene issues. Industrial Revolution from 1765-1782, with James Watt developing steam engine, resulted in reduced necessity for human muscle power and the consequent employment of children for many tasks, which was not a good experience. Public health professionals, using height and weight as tools, then recognized a decline in child health that was related with urbanization and industrialization. There were many instances which suggested decline in health parameters for children. Acts came into action that regulated working hours and prohibited underage children being employed.

Nineteenth Century Contributions

Statistical methods

Lambert Adolphe Quetelet published the first data of growth of height and weight of children which was statistically complete way back in 1835. He was the first researcher who made use of the concept of ‘normal curve’ which is now commonly referred as normal distribution curve. He used this to define the distribution of his growth measurements and emphasized the significance of measuring children rather than individuals to assess normal variation in growth. Subsequently, Luigi Pagliani in Europe followed Quetelets statistical approach beginning his studies on size and fitness of Italian military personnel. Later he applied his method to children and in 1876 proved that orphaned and abandoned boys in the ages 10-19 years when given care at a state-run agricultural colony improved in growth status and vital capacity. He also established that children of higher social classes fared better in height, weight and vital capacity when compared to poverty struck children.

Racial factor in growth

In United States a political debate necessitated the use of growth data. Henry Pickering Bowditch from 1875 collected data on height and weight of school children taken by teachers. He described the differences in growth related to sex, nationality and socioeconomic level between his sample of children, applying modern statistical techniques and published series of reports later. It goes to the credit of Bowditch to construct percentile growth charts published in 1885. According to him, the children of labor class were smaller than those of non-labor class for which he preferred an environmental explanation rather than genetic. But this was not in agreement with Galton who had demonstrated the heritability of stature and other physical traits in his book Natural Inheritance in 1889. Galton’s work made some believe that heredity was all totally controlling the human form and functional proficiencies. Basically his work held importance to the supporters of eugenic movement which claimed to be capable of improving human species by controlled breeding. Boas shattered the position of eugenicists with his study of migrants to United States and their children. Thereby, Bowditch and Boas demonstrated using statistical tools that eugenicists assertion that ethnicity could be determined by physical measurement was not true. Yet many eugenicists and politicians called for quotas on the so called inferior people into United States. Despite Boas presenting his report to US Congress,
American Congress passed the ‘Immigration Restriction Acts’ in 1921 and 1924 which explicitly directed southern and eastern European and Asian for migration quota. Boas and environmentalist may have been unsuccessful in the political battle but their work inspired three generations of anthropologist, public health workers and epidemiologists and even others in related fields.

Twentieth Century Contributions

Boas’ scientific findings hold lots of importance; be it the methodology of growth studies or the significance of calculating growth velocities from the measurement of individual rather than sample means and even the concept of ‘tempo of growth’ to facilitate in understanding the difference between early and late maturing individuals. The first half of twentieth century witnessed contributions of several longitudinal studies from United States and Europe. Additionally, for better quantification of amounts and rates of growth of healthy children, technologies like radiology, physiology and psychology to characterize the biological maturation were used. Another aspect that emerged out of these longitudinal studies was the causes of individual differences between people; this probably was an outcome of Boas work on environment determinants of growth and physical development.

The American studies

Initially the American studies were financed by private donors particularly the Rockefeller Foundation and Laura Spellman Rockfeller Memorial Fund. Lawrence K Frank maintained funds and assisted start and retained practically all major longitudinal studies. Ultimately longitudinal studies got its due recognition with United States National Research Council building Committee on Child Development in 1923 leading to several White House Conferences on Child Health. Publications of specialized journals, such as ‘Child Development’ in 1929 and ‘Growth’ in 1937, were the invaluable contributions to the cause of growth research. The study of normal growth, being of national importance both with its scientific and political value, gained momentum. Several important large scale long-term studies were initiated including the Fels Study, Harvard Growth Study, University of Iowa Child Welfare Station Study, University of Colorado Child Research Council Study, to name a few. The studies in general were interdisciplinary with physicians, psychologists, anthropologists and others; taking a global approach- they studied ‘the whole child’. They were particular in methodology of data collection, collated data as an end in itself, never put forward any research question about human growth and they just planned to continue data collection for 15 years or more. Fels Longitudinal Study which began in 1929 was the only one which has survived till date, others disappeared for various reasons. The sample of Fels Study constituted healthy, well nourished boys and girls living in small urban communities and rural areas of southwestern Ohio. Participants were measured for weight, height and variety of other physical and psychological characteristics once a year from birth to maturity. According to Alex F Roche in 1992 Fels study remained feasible since the members of the staff were keen to use data, answering vital queries on human growth, development and health. Another landmark was the work of Frank K Shuttleworth who used Harvard Growth Study to design new statistical methods to analyze longitudinal data. In his first report in 1937 he used methods that are still used today. Works of Howard Meredith, Thomas Wingate Todd, Katherine Simmons, A R Behnke, Keys J Brozek, N. Bayley, R. E. Scammon and Boyd are landmark contributions in the field of Human Growth and Development. They are credited with immensely important work in this field and hold practical significance in current scenario too.

The European studies

European longitudinal growth research had a delayed start as compared to United States, probably due to the two World Wars. The 1920s witnessed two important longitudinal studies. Alexander Low conducted Aberdeen Scotland study in which
he measured new born annually till they turned 5 years. Data was not analyzed appropriately till Tanner in 1956 gave correlation between measurements at different ages. Rachel Mary Fleming conducted the second longitudinal study and recorded annually stature and head dimensions of 3 to 18 years old individuals in England and Wales. In 1933 her analysis included a longitudinal curve of growth in stature, head length and head breadth for all the participants and she noticed normal individual differences in mode and tempo of growth. She also observed the growth stunting caused by combination of inadequate food intake plus energy expended in commuting to school. E. M. Widdowson too found that negative emotional environment during school mealtime could subdue physical growth. Fleming was responsible for changing social policy, particularly the introduction of free school lunch programs for undernourished children and necessity to identify such children.

Longitudinal studies by J. Ryle, R. Acheson, J. M. Tanner, R. Whitehouse along with British Harpenden study and International Children Center sponsored studies are important milestones of research in Human Growth and Development in Europe.

**Developing world- Longitudinal studies**

International Children’s Center gave financial assistance for longitudinal studies in Africa, the Dakar and Kampala. By 1960s the data was analyzed and some results were available with perplexing conclusions. There was no uniformity in the results of these studies as in some respects African infants and children were advanced over Europeans and vice versa. Although, some assigned genetics as contributor to the difference but others looked more towards ecology of human growth of Africa and its history – which actually meant poverty. Robert McVean in 1948 worked on longitudinal study of child, juvenile and adolescent development as the basic research project in a school. All the children who were attending the school were measured for weight, height, hand grip strength, eruption of permanent teeth, hand wrist X-ray take and several tests for cognitive development and school performance administered all under the Longitudinal Study of Growth and Development of Guatemalan School Child. This became the first large-scale mixed longitudinal investigation of human growth. The highlight of the study was that the subjects of different starting ages were measured for several years, i.e. the overlap in ages meant that data covering much or all of the growing years may be composed in just a few years than in two decades. Lots of data was collected without much analysis, until American Anthropologist Barry Bogin entered the picture. His contribution includes adding triceps and subcapsular skinfold and arm circumference to body composition for assessment of better nutritional status and adding Maya population in the study. American School Study and its enlarged successor was first major research program of its type in any developing nation. It is still continuing today making it the longest lived project of its kind. Programs of Institute of Nutrition of Central America and Panama (INCAP) gave invaluable contribution in strengthening of Human Growth and Development studies.

**Hormonal control**

According to Tanner in 1960s there didn’t exist any entirely convincing and coherent theory of endocrinology of adolescence. Infact perception on endocrinology of growth at other stages of life: prenatal and postnatal was also not good. Way back in 1974, Melvin Grumbach and colleagues suggested several convincing and coherent theories on endocrinology of growth. This paved way for models and theories of hormonal control for all the other stages of growth. The technological advances in the evaluation of hormonal factors and progress in appreciating how hormones exert their influence on human growth and development are responsible for rapid research. The history of human growth hormones (HGH demonstrated in 1944) and insulin-like growth factors (IGFs first in 1957) are examples. Anthropological interest was generated by the breakthrough of human population differences due to the presence of these hormones—African pygmy appear to be deficient of one of the IGF’s or its
receptor. Endocrine glands like thyroid, adrenal, ovary and testis secrete hormones along with six hypothalamic and eight pituitary hormones and other growth factors regulate human growth. Initial information on hormone regulation was provided by children with endocrine pathologies. Non-invasive methods like using saliva instead of blood facilitates in including wider spectrum of normal children would enable in more detailed insight of endocrinology and growth.

**Technological advancement and basic research concerning growth**

Twentieth century saw the research into genetics of growth. The rediscovery of Mendelian laws in 1900 and the DNA characterizations in 1952 were probably two historical events that had bearing on growth research. Stress on ‘racial genetics’ paved way for modern population genetics by early 1950s. As a consequence of many genetic studies, the unraveling of impact of environment on growth was witnessed. There are a number of examples which you would be reading in following units to understand the impact of environment and genes on growth.

The technical foundation of growth research lies in the accuracy of instruments used for body measurements along with the standardized and reliable methodology. Invention of anthropometer by J S Elsholtz in 1654 was a landmark in growth research. Development of skinfold caliper, radiography, photogrammetry along with advances in data collection methodology and statistical treatment have taken growth research to different heights.

Inputs from the public health in 19th century and contribution of large scale longitudinal studies of 20th century provide invaluable data. Progress in molecular biology, nutrition, social sciences and endocrinology gave impetus to direct the study of human growth and development into research and medical specialty. The data and technical advances were primarily descriptive in nature describing how children grew and the effect of heredity and environment on growth, but were unable to explain why. A theoretical approach was required to follow the ‘why’ of growth and development. Charles Darwin’s biological research became modern theoretical science and the scientific method of experimentation and hypotheses testing were progressively more applied to biological issues including the control of growth and development. With the passage of time theory of recapitulation gave way to growth theory which had contribution in late 19th and early 20th century from many scientists. Thompson stands out amongst all visualizing growth as movement through time. He interpreted vividly that growth velocities in stature or weight were only unique cases of a more universal biological process. Thomson is credited with developing the concept and methodology of using transformational grids to quantify the course of growth during the lifetime of an individual or evolutionary history of species, leading to providing an intellectual strength to growth and development research; and inspired subsequent generations of growth researchers to deliberate about growth in new ways.

**1.4 AIM AND SCOPE OF GROWTH AND DEVELOPMENT**

Anthropological perspective for understanding human beings through time and space holds importance. In contrast to most other fields that have humans as their focal point, the anthropological approach to humankind draws on and integrates research about people from all parts of the globe, from past as well as contemporary cultures. An anthropological viewpoint on the course of life with respect to human growth and development patterns, will serve as a way of further illustrating the strength of this approach. There have been social motivations for growth studies. Examinations of the physical and physiological development of children began as a reaction to child labor reform movement during the nineteenth century. At this stage the eruption
of second molar was construed as a signal of puberty and considered old enough to work. Growth studies are also influenced because of medical concern which would include the monitoring the physical and developmental progress of children, nutritional requirement for normal growth and environmental effect on growth and medical aspects of growth and its abnormalities. The evolutionary studies of growth facilitates in understanding the interaction of growth and evolutionary biology of human species.

One of the best ways to explore the interaction of biology and culture in the human life course is by appreciating how humans grow, mature and develop in their own niches, because it is only in this phase, that human beings experience and reflect both biology and sociocultural environments. If we consider how a human develops from an embryo into an adult and examine the forces that operate on that process, only then we can have a better perspective of how both biology and culture influence our own lives.

There is variation in the degree to which cultural factors interact with genetically determined biological characteristics. It is these variable interactions that reflects the characteristics expressed in an individuals. There is no doubt that some genetically based characteristics will express themselves irrespective of the cultural context of growth and development. Features such as intelligence, body shape, and growth reflect the interaction of environment and genes. Each one of us carries certain genetic makeup right from birth that influences the maximum stature we can achieve in adulthood. But to attain that maximum stature, we must be properly nourished during our growing years and escape many childhood diseases and other stresses that inhibit growth. Socioeconomic status, a cultural factor, is probably one of the primary determinants of nutrition and health. The intricate effects of all these factors in singularity or in unison can be understood only by understanding the human growth course, tracing its trajectories and understanding its development either by comparison or on its own. Likewise, to understand human growth and development from an evolutionary angle, with an interest in how natural selection has operated on human life cycle from conception to death, a perspective known as life history theory, it is essential to know human life course. Is it a fact that humans have longer periods of infancy and childhood in contrast to other primates? What is that makes differences in such closely related species as humans and chimpanzees? Life history researches try to find answer to such questions. The whole life course characterizes a series of life history traits such as length of gestation, age at weaning, time spent in growth to adulthood, adult body size, and length of life span. Life history theory offers the foundation for appreciating many queries like how fast an organism will grow and to what size, how many offspring can be produced, how long gestation will last, and how long an individual will live. Nearly all mammals have at least three phases: prenatal, infancy, and adult and most primates have four phases: prenatal, infancy, juvenile (usually called childhood in humans), and adult. Humans add a phase between the juvenile phase and adulthood referred to as the subadult period (adolescence). Yet, among women there is an addition of a sixth phase - the post-reproductive years following menopause. Most of these intricate details can be appreciated only through a clear understanding of all aspects of human growth and development.

Majority of these life cycle stages portray biological transitions—the prenatal phase starts right from conception and ends with birth; infancy is characterized by nursing; childhood, or the juvenile phase, represent period from weaning to sexual maturity (puberty in humans); adolescence is the period from puberty to the end of growth; adulthood is marked by the birth of the first child and/or the completion of growth; and menopause is documented as having occurred one full year after the last menstrual cycle. For humans, these biological markers are not only growth milestones but hold cultural significance also. For example, puberty has different
meanings in different cultures. In many cultures a girl's first menstruation (menarche) is often marked with ritual and celebration; a change in social status typically occurs with this biological transition. It is also suggested that an adolescent stage of growth offers advantages in terms of learning social skills before reproduction, denoting that the girl has grown. Thus, evolution of human adolescence is distinct in having both biological and social dimensions. To understand the complex social connotations engaged in purely biological processes, it becomes imperative to know why, when and how these processes initiate. In non-western societies menopause is often associated with a rise in status for women whereas it is commonly seen as a negative transition for women in many Western societies. Collective and individual attitudes toward these life cycle transitions have an effect on growth, development, and health. Therefore these processes are to be known and understood in their time, intensity and space to understand human life cycle. Studies in human growth and development also include nutritional status which may reflect the health status of an individual.

1.5 SUMMARY

The Unit reflects upon the historical development of the human growth concept and the advances that have taken place in the study of human growth. After the basic principles of physical growth and development were known, researchers have been progressively unraveling the underlying biology of human growth. There is a common pattern of human growth and development during prenatal period and all normal well-nourished children follow same basic pattern from birth to maturity. Whatever we know today about human growth and development has an interesting history of intellectual development. Anthropological viewpoint for understanding human beings through time and space holds importance hence it is imperative to have continuity in studies on human growth and development.

Suggested Reading


Sample Questions

1) Define Growth and Development.

2) Why should you study Growth and Development?

3) Write a brief account of prehistoric and early historic periods in the context of human growth.

4) Discuss historical background of human embryonic and fetal development studies.
UNIT 2 BASIC PRINCIPLES OF HUMAN GROWTH

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Learning Objectives

By the end of this unit, you will be able to:

➢ define the terms Growth, Maturation and Development;
➢ differentiate between these basic processes of human growth;
➢ understand the concept of catch-up and catch-down growth; and
➢ define secular trend and understand the factors underlying it.

2.1 INTRODUCTION

The bio-cultural evolution of humankind has resulted in a pattern of growth and development that converts a single fertilized cell into a multicellular organism composed of hundreds of different tissues, organs, behavioral capabilities and emotions. Growth, maturation and development are fundamental processes that shape an individual's progression from birth to adulthood.

2.2 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.'

Growth may be defined as quantitative increase in size of the body as a 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, according to Malina et al. (2004), the cellular process responsible for growth can be summarized as:
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.

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.

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.

2.3 MATURATION

Maturation is often defined as the course of becoming mature, or advances towards the mature biological state which varies with the biological system considered, whether endocrine, reproductive, skeletal, digestive or immunological. These variations may be designated to differences in the timing and tempo of maturation. Timing refers to when a specific maturational event occurs, e.g. age at appearance of pubic hair in boys and girls or age at maximum growth during adolescent growth spurt, while tempo refers to the rate at which maturation progresses. Maturation of the nervous and endocrine systems is a major factor in sexual, skeletal and somatic maturation during late childhood and adolescence.

Individuals end up as adults with an entirely ossified skeleton, but they reach this juncture at different times and attain different adult heights. This offers fundamental difference between growth and maturation. Growth focuses on size attained at a given point in time, whereas maturation focuses on the progress rate in attaining adult size and maturity. However, both processes must be viewed as dynamic cellular processes targeting at the achievement of mature adult state from conception state.

2.4 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, 2010). Growth and maturation occur simultaneously with development but the latter denotes a broader concept that is used in two distinct contexts- biological and behavioral (Malina et al., 2004).

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 chiefly ensues early in prenatal life when tissues and organ systems are being formed and complete differentiation is attained with the onset of function in a particular tissue. The course is regulated by activation or repression of set of gene interacting with hormones and nutrition.

In behavioral context, it relates to the development of competence in a variety of interrelated domains as the child adjust to his or her cultural milieu- the amalgam of symbols, values and behaviors that characterize a population. It also denotes acquisition and refinement of behaviors expected by the society.
2.5 CATCH-UP GROWTH

The intricate phenomenon of human growth and development is regulated in predetermined trajectories by the genetic potential. In an unconstrained environment, individual exhibits a pattern of growth that is more or less parallel to or within this imaginary “canal”. However, none of us has lived or been brought up in a completely unconstrained environment. Towards the end of intrauterine life, our growth was constrained by the size of the uterus. During infancy and childhood, we succumbed to an array of diseases resulting into reduced appetite and absorption of nutrients. Through such circumstances, growth would have reflected the effect of the insult by slowing down (known as catch-down growth) or in a more severe case, would have ceased (Cameron, 2002). The amount of deviation from the predetermined growth pathway and reduction in growth velocity depends on the duration and severity of growth retardation and the insult and the age at exposure (Tanner, 1981). A child who suffers from an illness or starvation is able to return to or nearly approach his regular course of growth when conditions improve. The ability to stabilize and return to a predetermined growth curve after being pushed off the trajectories persists throughout the whole period of growth and is commonly seen in response to illness or starvation. This phenomenon was termed canalization or homeorhesis by a British genetist, C. H. Waddington in 1957 (Harrison et al., 1998). During such recovery phase, his initial growth velocity is above that of normally expected for children of his age or even of his skeletal maturity. This rapid increase in growth velocity following a short term period of starvation or illness is termed as catch-up growth. The growth velocity declines as the child recovers. Catch-up growth may completely restore the growth scenario to normal or, if the insult was severe and very prolonged, it may be insufficient to do so.

In Kenya, Kulin et al. (1982) conducted a cross-sectional survey comparing girls from three privileged schools in Nairobi against an impoverished rural district with a very high prevalence of malnutrition. By the age of 18 years, the previously malnourished rural children had completely caught up with the affluent girls. Thus, it is clear that substantial catch-up in height to totally eradicate a deficit is possible even after the early stages of growth. Also it is unreasonable to expect that those who developed stunting associated with poverty will catch up spontaneously without a major change in their circumstances. The follow-up of previously malnourished children in Chile, Peru and Cape Town (Alvear et al., 1986) showed a remarkable evidence of spontaneous catch-up when provided with optimum nutrition, though they did not achieve normality. Satyanarayana et al. (1989) reported that undernourished children of rural Hyderabad entered late into puberty, with significantly depressed intensity, but gained height similar to well nourished British children, as a result of prolonged adolescent growth spurt, which continued till 19-20 years. Earlier, potential for catch-up growth among stunted children was thought to be limited after age of 2 years, associated primarily with high rates of infection and inadequate nutrition related to poor weaning practices and poor dietary quality. However, investigations by Adnair et al. (1999) indicate that there is a large potential for catch-up growth in children even into the preadolescent years.

2.6 SECULAR TENDENCY

The attainment of larger size and acceleration of maturation over several generations are collectively labeled as the secular trend. It includes several trends—increase in height and weight during childhood and adolescence, reduction in the age at menarche and reduction in ages of attaining other indicators of biological maturity. These are reversible and complex phenomena that reflect the remarkable sensitivity, or plasticity, of the growth and maturation processes to the environmental conditions under which children and adolescent are reared (Malina et al., 2004). The period
of secular changes evident in different population varies in response to differential rates of improvement in environmental influences related to nutrition, physical activity, socio-economic status and health. In a review of secular trends taking place in industrialized nations of the world, Hauspie et al. (1996) offer the following overview:

"Secular changes in body size and tempo of growth have occurred during the last century in almost all the industrialized countries and have been well documented.... almost all of the secular increase in adult height is established during childhood.... The secular increase in body length is due predominantly to an increase in leg length...the legs are the fastest growing part of the body during early childhood when the impact of the environment is greatest.....Secular changes in body dimensions has occurred simultaneously with the secular change in tempo of growth, as shown during the last 100 years by an advancement of age at menarche and at peak height velocity of about 3-4 months per decade in most European countries....The higher tempo of growth has resulted in adult height being reached at an earlier age for males adult height is now reached at about 18 years but in the 1910s was only reached at about 26 years of age..."

Secular trends can be:
Positive
Negative
Absent

2.6.1 Positive Secular Trend

In the contemporary period, children on an average are taller, heavier and mature earlier than those of several generations ago indicating positive secular trend. Hauspie and colleagues (1996) reviewed the evidence for these secular trends in 17 nations including many European countries as well as Japan, Cuba, Brazil, North America and Taiwan. They found that, following World War II, the Japanese experienced strongest secular trend so far recorded for an entire nation. In 1950 the mean height of Japanese young adult men was 160 cm, whereas in 1995 it was almost 172 cm. Over the period of 45 years height increased at an average rate of 2.67 cm per decade. The rate of change was much faster in the first decade (about 4 cm) than in the last decade (about 1 cm). In contrast, the rate of secular increase in height in Sweden and Norway, between 1952 and 1985, was only 0.3 cm per decade.

Positive secular changes in the height of children and adolescents are largely, but not entirely, related to earlier maturation, as evidence by adult trend in comparison with pre-pubertal children (Cole, 2000; Krawczynski et al., 2003). Concomitant to the positive secular trend in height and dramatic increase in childhood weight, increased prevalence of obesity has been widely reported in almost all developed and developing countries in the last two to three decades. Pacific have the highest prevalence of overweight among children (approximately 20-30%), whereas parts of South East Asia and much of Sub-Saharan Africa appear to have the lowest values (Wang and Lobstein, 2006).

Secular trend takes place not only within a region or country but also with migration of individuals from one place to another, which may be associated with the movement from low socio-economic status (SES) to higher SES or in situ socio-economic improvement (Bogin, 2001). The ‘migration effect’ on secular trend can be substantiated by the classic work of Boas (1940) with European children. These children experienced increase in height when they migrated to United States. Japanese immigrants to Hawaii were significantly taller than their parents residing in Japan (Shapiro, 1939). Greulich (1976) showed that Japanese children born and brought up in California (America) grew to be taller than Japanese children born
and brought up in Japan. Follow up study of these same population shows that the
growth in height of each generation of the children of migrants continues to increase
until it converges on that of the host population (Roche, 1979).

Sometimes the rate of the secular trend is much more rapid than these classic
cases. The ‘Maya in Disneyland’ showed a rapid change in amount and rate of
growth. In less than one generation, the Guatemalan Maya refugee children living
in Indiantown, Florida and Los Angeles became 5.5 cm taller, on an average, than
their age mates at Guatemala. These evidences suggest that the plasticity of human
phenotype changes at different rates for different traits (Bogin and Loucky, 1997).
Maya children were compared with three different ethnic groups: the Whites, the
Blacks and the Mexican-Americans. They were shorter than other groups and
weighed less than the Whites and the Blacks but did not differ significantly from
Mexican Americans. There was no ethnic difference in body composition measures
such as arm fat area or for arm muscle area. Thus, in terms of energy and protein
Maya children appear to be generally healthy and well-nourished but why shorter
(Bogin, 2001)?

This evidence shows that the plasticity of human phenotypes changes at different
rates for different traits. In most studies referring to positive secular trend, the
increase in mean height from generation to generation lags behind increases in
weight and body composition. This could be explained as height reflects health and
nutritional history, weight and body composition reflect recent events (Taylor and
Bogin, 1995). With reference to the ‘intergenerational effect hypothesis’ a child’s
height is an historical record of both the individual and his or her parents. Incase
of the Maya refugee, the effects of chronic undernutrition and disease suffered by
the parents are still being expressed in the growth of their children. Conversely,
children who are better nourished and healthier will give their own offspring a
healthier prenatal start in life (Bogin, 2001).

A review of secular trend among the adult Indian population has presented a
comprehensive, empirical description of mean height differences and the underlying
variation among adults in India across diverse socioeconomic, demographic, and
geographically oriented groups as well as birth cohorts. It has indicated an increase
of 4.5 cm per decade in men’s height, which is similar, albeit modest, compared to
changes shown in nations experiencing economic transitions whereas adult stature
increase over the past decades varied between 0.3 and 3.0 cm/decade across Western
countries. This is in contrast to women in India who have experienced little growth
in height with increases in year of birth (0.1 cm per year). Although there has
been increased economic growth in India, there is considerable evidence of little
improvement in nutrient intake, especially in rural areas (Perkins et al., 2011).

### 2.6.2 Negative Secular Trend

Children shorter, lighter and maturing later than previous generations are indicative
of negative secular trend. A discriminant incidence of the negative trend comes
from Guatemala during the period from 1974 to 1983, a time of intense civil war
and political repression. The cross-sectional samples of 10- and 11- year old boys
and girls from families of high, moderate and very low socio-economic status
revealed discernable decline in the mean stature (Bogin and Keep, 1998). A general
deterioration of the quality of life in Guatemala, especially the quality of nutrition
and health of the population seems to be the major cause of negative secular trend.

Puberty is an important milestone in reproductive life and secular changes in the
timing of puberty may perhaps reflect the general reproductive health of a population.
Recently, a large cohort of Danish school children has demonstrated secular trends
in the age at onset of pubertal growth spurt (OGS) and the age at peak height
velocity (PHV) during puberty in four decades (1930-1969). Age at OGS declined
significantly by 0.2 and 0.4 years in girls and boys, respectively, whereas age at PHV declined by 0.5 and 0.3 years in girls and boys, respectively (Aksglaede et al., 2008). A longitudinal study on Indian children and adolescents enrolled in Sri Aurobindo International Centre of Education (SAICE), has also revealed decline in the age at OGS and at PHV in girls over four decades (1950–89) whereas the same parameters were constant in boys (Virani, 2005).

Age at menarche is closely linked to the general process of development and is rigidly constrained by biological limit. In Poland, age at menarche declined from 1955 to 1978 by about 4.15 months per decade for girls living in villages and towns. For city girls the decline was 3.0 months per decade. Despite the higher rate of decline for village and town girls, the city girls have always had the earliest mean age at menarche. In 1955, the mean ages were: village 14.3 years, town 13.9 year and city 13.4 years and in 1978 these mean ages were 13.5, 13.1 and 12.9 years, respectively. The differences were attributed to the lower quality of nutrition, health care and greater physical labors in town and villages compared with cities (Hulanika and Waliszko, 1991). In India, an increase in stature and decrease in age at menarche was reported when daughters were compared with their mothers thereby indicating the presence of secular trend in the Punjabi Arora females (Khanna and Kapoor, 2004). Studies on mean menarcheal age of Maharashtrian girls, from 1960s onwards to 2000, have shown a consistent decline of age at menarche on an average, by about 6 months per decade as compared to 3-4 months in some countries of Europe, North America, and several parts of the world. It reflects the improved socio-economic, nutritional and general health conditions in India as compared to these countries where similar standards were achieved much earlier (Bagga and Kulkarni, 2000). The Saharia, a primitive tribal group of Madhya Pradesh, depicts lower mean age at menarche among daughters (13.3 years) than their mothers (13.5 years). This may be attributed to the improved socio-cultural life as a consequence of shift from traditional practice of cultivation, hunting, gathering, pastoralism to daily wages (Biswa and Kapoor, 2004).

2.6.3 Absence of Secular Trend

A population may have attained or is near its genetic potential for height and timing of maturity, so further changes may not be possible. On the other hand, a population may be living under environmental conditions that have not sufficiently improved or impoverished over time to induce positive or negative trend, respectively (Malina et al., 2004). For example, the persistence of traditional agricultural practices, relatively poor farmland and limited economic resources for the improvement of agriculture is characteristic of many rural areas in developing countries. Lifestyles are also changing in some rural areas, resulting in a shift from subsistence farming to cash crops in parts of Latin America or to a ‘depastorized’ lifestyle in some parts of Africa (Malina, 1990). Crowded living conditions, especially in rapidly growing urban slums, inadequate or marginal nutrition, disease and associated social stresses persist in many developing countries. These conditions have similarities to those that were persistent in Europe in the 18th and 19th centuries, during which no secular trend was observed (Malina et al., 2004).

The interrelated aspects contributing to secular trend may include:

- Elimination of growth inhibiting factors such as epidemic and endemic disease or reduction in their incidence rate, a condition conducive to the transmission of infectious microbes. With reduced infectious disease load, energy and nutrients that would have diverted to ward off infection would now be available to support the cellular processes of growth and maturation.

- Favourable economic circumstances as indexed by a blend of family income, occupation, education level of parents, deciphered as improved living conditions
and nutrition for growing and maturing infants, children and adolescents. Thus, improved nutrition and public health work synergistically with reduced infectious disease load.

- Genetic changes such as population admixture or increased outbreeding have occurred with increased migration and interclass mobility, but changes associated with heterozygosity are rather small in the context of the major changes that characterize secular trends.

2.7 SUMMARY

Several environmental factors have an impact on the somatic growth and maturation. These factors act independently or in concert to modify an individual's genetic potential. Suboptimal energy intake for a continued period of time, which could be ascribed to illness or heavy exercise load, could for the time being delay growth, but would be followed by catch-up growth upon intake of adequate nutrition. Slowing down of the growth is in reaction to sub-optimal energy intake and children with nutritional growth retardation reach a new energy equilibrium phase between their genetically determined growth capacity and the current energy intake. However, long term nutrition and socio-economic situations lead to inter-generational change in body size and ages at reaching biological maturity. These developments are complex phenomena that echo the significant plasticity of the processes of growth and maturation to the environmental conditions under which an individual is raised.

2.8 REFERENCES


Goldstein, M.S. 1943. *Demographic and Bodily Changes in Descendants of Mexican Immigrants Austin*; Institute of Latin American Studies.


**Suggested Reading**


**Sample Questions**

1) Define growth, maturation and development.

2) What do you mean by catch-up growth?

3) Describe the secular trend and its types.

4) Elaborate the factors underlying the secular trend.
UNIT 3  APPROACH TO HUMAN GROWTH AND DEVELOPMENT

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3.2  Growth Process
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Learning Objectives

Once you have studied this unit, you should be able to:
- explain the meaning of growth and development;
- discuss the techniques and methods of studying growth;
- understand the different stages of growth; and
- highlight the different factors that affect the growth process.

3.1  INTRODUCTION

In this Unit we are going to understand the meaning and process of growth, development, its stages and approaches to the study and different factors that control the process of growth at different stages. We shall also study the growth process and ecological conditions in the context of growth.

The study of growth is an important aspect of biological anthropology. But the question arises as to why importance has been given to growth studies and what is its relevance. Biological anthropologists study various aspects of human evolutionary process in detail. In addition to the evolutionary changes in morphology, they also want to know the different types or patterns of growth that took place in different human evolutionary stages.

It is obvious that the study of growth throws light on the evolutionary mechanisms. With the help of growth studies we can also make out the morphological differences that exist among people belonging to different racial groups that are distributed in different parts of the world.
With these basic points in the mind, we are going to discuss about other relevant information regarding the growth process.

### 3.2 GROWTH PROCESS

Now we shall try to understand some of the basic terms concerning the growth process. The term growth and development are sometimes used as synonyms. But when we examine these two terms the meaning is slightly different. Growth can be defined as the increase in the size of organism or any of its parts by the way of multiplication of cells. Mainly growth is physical but development refers to the increase in functional capacity in perfect form resulting from specialized tissues. Development also depends on certain physiological functions in the body. At the same time, we cannot ignore the mental development for which we sometimes use the term personality. Personality can be defined as the overall complexity of an individual resulting from an interaction of physical, physiological and psychological attributes.

In growth and development interaction of several processes are involved. Growth is primarily determined by hereditary components but is also influenced by exogenous environmental factors. But in development though there is a hereditary base, but manifestation may be influenced mainly by external factors.

### 3.3 GROWTH MEASUREMENTS

Here, we will understand about the growth changes that occur from one age group to another age and also at different stages. To study the growth process, it is essential to make observations through measurements. In nutritional studies growth measurements give us very valuable information.

There are three basic types of measurements of growth. Firstly, the linear which are usually evaluated in terms of increase in length, e.g., stature, sitting height, head length etc. Secondly, the circumferential measurements that include head circumference, chest circumference, mid-upper arm circumference, etc. Lastly, the ponderal measurements that refer to weight or mass. Growth is measured in inches, centimeters or millimeters and in kilograms and pounds.

### 3.4 GROWTH CURVES

Now let us discuss about the growth curves, which will give us the idea of the growth that takes place at different stages. The measurements taken at different ages are plotted in the form of a graph. Based on this, two types of curves can be drawn, namely distance curve and velocity curve. Growth is always considered as a form of motion. Hence, it can be observed at different ages and also at different stages. The growth movement is not same in all body dimensions. The first curve can be drawn for continuous growth. For example, the growth of the stature is always in an upward direction from lower age group to higher age groups. It is also considered as fastest rate of growth when compared to other dimensions. This curve is called is distance curve. Secondly, in other dimensions, there is a different rate of growth in between age groups. For example, the curve drawn to denote growth of the head dimensions between two age groups is plotted in the form of graph is interpreted as velocity curve. The velocity curve plots the amount gained in a given time, e.g. in one year. It measures the rate of growth at a given time for a particular body parameter, e.g. height.
3.5 TECHNIQUES OF STUDYING GROWTH

Let us now examine the different techniques used to measure the body dimensions. Firstly, the anthropometric technique wherein measurements on different parts of the body are recorded to know the extent of growth that takes place at different intervals. This technique involves many measurements which are recorded with the help of different landmarks on the human body to study growth. To take these measurements specialized instruments have been designed. To take measurements, it requires expertise on the part of the investigator who is involved in growth research.

Secondly, let us see how the skeletal growth is studied to know the developmental aspects of growth. With the help of roentgenometric technique the X-ray photographs are taken on an individual to evaluate skeletal growth. This process gives us important clues about the stages of development of the different bones in the body. This technique can also be used to study dental maturity on the basis of stages of calcification of teeth as seen in jaw X-rays in just the same way as we assess the skeletal growth.

3.6 METHODS OF STUDYING GROWTH

After knowing about techniques of studying growth, now it is essential for us to know about the different methods adopted by researchers to record the growth data. The first method is cross-sectional method, wherein the subjects involved in the study are measured only once in their life time. That means the subjects who are selected in a particular age group are not same when measurements are recorded in some other age group the second time. This method is very popular because it is quicker, cheaper and less laborious. In most of the growth studies, this method is used.

The next method is the longitudinal method wherein the individuals are measured more than once in their life time. Longitudinal studies give correct information on individual variations in the rate of growth in particular age-groups. Such studies are time consuming, costly, laborious and also require lot of patience on the part of the investigator. This study has its limitations.

The third method is the mixed longitudinal method wherein children of a particular age-group are sometimes added to the already ongoing longitudinal study. But for certain reasons, some of the children may not be available for the next time measurement in a longitudinal study. They are then replaced by another set of children to keep the continuity. This type of study is more complicated and special statistical tools are required to get maximum information out of mixed longitudinal growth data.

3.7 STAGES OF GROWTH

Now let us understand about the different stages of growth. A simple classification includes prenatal and post natal stages of growth. Prenatal growth includes the growth of the embryo and fetus. The post natal growth includes infancy, childhood, adolescence, puberty, adulthood and senescence.

Prenatal growth

Prenatal growth includes embryonic and fetus stages. During embryonic stage, though the rate of growth is slow, it gives rise to the development of different parts like head, legs, arms and other parts. The cells are differentiated into specialized tissues, like nerves and muscles. When this stage is completed, embryo becomes childlike in appearance.
Postnatal growth

This stage can be described from birth up to adulthood.

Infancy

Infancy usually comprises the first year of postnatal life. During infancy the growth is very rapid. More than 50% of the birth length and 200% of birth weight takes place during the first year of life.

Childhood

Childhood generally spans from the end of infancy to the beginning of adolescent period. It may further be divided into early childhood, middle childhood and late childhood. The early childhood is the period of eruption of deciduous or milk teeth. The permanent dentition also shows its beginning. The head in relation to the trunk continues to predominate but in lesser degree. During this phase, the growth is relatively more in width than in height. The middle childhood period (sometimes also called juvenile period) is described between 7 and 10 years of age-group. During this time, the linear growth of the body takes place rapidly. The waistline becomes definable. Between 7 and 8 years a nominal acceleration in the rate of growth occurs. Normally the changes that take place during this period are termed juvenile growth spurt.

Broadly, the late childhood begins from the pre-pubertal period and continues up to the time of puberty. The late childhood phase of growth starts from 7 to 8 years age group and continues till puberty (between 13 and 16 years among boys and between 12 and 15 years among girls). The secondary sexual characteristics normally appear during this phase in both the sexes. The growth changes that occur during this particular stage are also referred to as the adolescent growth spurt.

Adolescence

Childhood is followed by adolescence period. The adolescence period extends from the time of puberty till around 20 years. During this period there is a marked acceleration of growth, which is commonly known as the adolescence growth spurt. The acceleration of growth at adolescence causes many anatomical changes almost in all parts of the body. Differentiation in primary and secondary sexual characteristics also takes place during the adolescence period. This period is marked by changes in the reproductive organs, in body size and shape and in a variety of physiological functions. Under the influence of hormones, sexual maturation takes place during this period.

Adulthood

An important sign of adulthood is reproductive maturity. In both the sexes we find lot of physical and physiological changes which lead to an altogether different type of appearance. During this period, we even find psychological changes. On an average, adult males are heavier and taller than adult females.

Senescence

After the prime period of adulthood, senescence that is old age starts. The aging pattern shows great individual variacion. The aging time also differs from person to person and society to society, because the environment plays an important role. During this period, many molecular and cellular changes occur. These changes are measurable and also can be described, but these do not exhibit any specific pattern or well-defined sequence. It appears there is no definite biological plan for aging process but multi-casual mechanisms are involved in this process.
3.8 SECULAR TRENDS

Let us now try and follow the meaning of secular trend. The secular trend is the tendency over the last hundred or so years for each succeeding generation to mature earlier and grow larger. This trend has occurred worldwide. In the twentieth century, the mean body height from decade to decade has increased. Even the mean body weight has also increased. Other features, such as early menarche, have also demonstrated secular trend. One thing is clear that such data have been collected from children who were regularly getting normal nutritional food. The adverse conditions have yielded negative results especially during World War I and World War II period.

What causes these secular trends? Some researchers believe that a general improvement in nutritional, better sanitation, better health services and less tedious life styles are responsible. These factors have permitted individuals to come closer to their genetically determined potential weight and stature. Today a leveling off the secular trend appears to be occurring among the higher socio-economic urban population. It must be pointed out here that all positive secular trends are not desirable. For example, increased levels of adiposity without corresponding increase in height noticed in some parts of the world are associated with increased prevalence of obesity, particularly among children and adolescents, which is known to be a health risk.

3.9 GROWTH GRADIENTS

One way in which the organization of growth shows itself is the presence of maturity gradients. It indicates that different dimensions of the body show the variation in their rate of growth. It appears that growth is fastest in stature until maturity is reached. But this rate is not applicable to other dimensions of the body. So they have their own rates of growth. Even growth gradients differ from males to females. Some dimensions cover small areas only and operate for short period while others cover whole systems and operate throughout the growth period. In some cases, we even find different proportionality between different parts of the body.

3.10 THE INTERACTION OF HEREDITY AND ENVIRONMENT IN CONTROLLING GROWTH

In this sub-unit, it is very interesting for us to discuss about the interaction of heredity and environment in determining the growth process. Many factors that affect the rate of growth are known. Some are hereditary in origin and act by hastening or retarding physiological dietary restriction, season of the year or 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 heredity and environmental influences.

3.11 GENETICS OF GROWTH

Genetic factors are clearly of immense importance. The genetic control of tempo of growth is exemplified most simply in the inheritance of age at menarche. Identical twin sisters reach menarche an average of two months apart and non-identical twin sisters an average of 10 months apart. The correlation coefficient between age at menarche of mother and daughter is about 0.4. Similarly, the skeletal maturity shows a close correspondence at all ages in identical twins. The time of eruption
of teeth, both deciduous and permanent and also the sequence in which the teeth calcify and erupt, is largely determined by heredity. Not all genes are active at birth. Some express themselves only in the physiological surroundings provided by the later years of growth, whose effect is said to be age limited.

### 3.12 NON-GENETIC FACTORS OF GROWTH

#### Race, Ecology and Growth

There are racial differences in rate and pattern of growth, leading to the differences seen in the adult build. Some of these are clearly genetically determined while others depend perhaps on climatic differences and certainly on nutritional ones. Many examples can be given on this issue from different racial populations distributed in different parts of the world.

Altitude and climate are other factors associated with differences in the body size, body proportions and body composition. It has been found that people in colder climates show tendency to be heavier with relatively large trunks and shorter legs. On the other hand, in warmer climates they tend to have lighter and longer legged body. Populations living in warmer climates have large body surfaces than those in colder climates. The Africans who live in hot dry climate show tendency to be taller than in those who are living in hot-wet climates.

#### Season of the Year

In most growth data, from industrialized countries in temperate areas a well-marked seasonal effect on growth velocity can be seen. Growth in height is on average fastest in spring and growth in weight fastest in the autumn. The average velocity of height from March to May is about twice that of from September to October in most of the western European data.

#### Nutrition

Growth is closely linked with nutrition. An adequate supply of various nutrients such as proteins, carbohydrates, fats, vitamin, minerals, water, etc., is necessary for general growth of the body. Nutritional deficiencies retard normal growth during childhood and delays further growth process.

During post-war periods (World War I and World War II) several studies were conducted in different parts of the world to assess the effects of diets on growth. During that period there was a shortage of food supply in some populations. The people were under nourished. As a result, the children of those populations were shorter and lighter. But after restoration of normal food supply both height and weight of these populations showed uniform increase. The children have the great recuperative capacity.

#### Social-cultural and Economic Conditions

The social-cultural and economic conditions also play an important role in determining the course of growth process. It is very difficult to separate one element from the other. We can mention here about the role of socio-economic classes, size of the family and cultural behavior in growth studies.

Some studies reveal that the children of upper socioeconomic classes are taller and heavier than those of the lower socioeconomic classes. The size of the family exerts an indirect influence on the rate of growth. In large families with limited income, children do not get adequate quantity of food. As a consequence their growth is affected. Cultural factors, such as taboos associated with various foods, may also influence growth.
Psychological Disturbance

The secretion of growth hormone is affected by the emotional and psychological environment of a person. Hence, physical growth is related to psychological factors also, which are again associated with family and social environment. Under favourable psychological environment the endocrine system functions properly and as a result children show normal growth. Better living standard, medical care, good hygiene and sanitation, etc., create normal psychological environment which is essential for normal growth process.

We have now acquainted ourselves with some of the fundamental concepts of Human Growth and Development. In subsequent blocks you will learn these concepts in greater detail.

3.13 SUMMARY

The study of growth and development is very important in biology as it throws light on the mechanism of evolution. Though growth and development are different terms, sometimes these are used interchangeably. Anthropometric technique is the most popular techniques of studying growth and employed by many researchers. Growth can be studied by three methods, i.e., cross-sectional, longitudinal and mixed longitudinal. The cross-sectional method is economical and less time consuming but longitudinal method is expensive and time consuming. That is why most of the investigators employ cross-sectional method for their research work. Growth is determined by plotting distance and velocity curves which indicate the continuous growth rate and the rate of growth, respectively, between two age groups. There are different stages in growth, i.e., pre-natal and post-natal. The latter includes infancy, childhood, adolescence, adulthood and senescence. There are genetic and non-genetic factors which affect the rate of growth. Non-genetic factors include nutrition, ecology, socio-economic condition, race, psychological disturbance, etc.

Suggested Reading


Sample Questions

1) Explain the importance of studying growth.

2) Mention the different techniques and methods of studying growth.

3) Write about the different stages of growth.

4) Briefly discuss about genetic and non-genetic factors that control the growth process.