



**HUMAN GROWTH AND DEVELOPMENT**

THE PEOPLE'S  
UNIVERSITY

**School of Social Sciences**  
**Indira Gandhi National Open University**

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## CONTENT

		Page No.
<b>BLOCK 1</b>	<b>FUNDAMENTALS IN HUMAN GROWTH</b>	<b>9</b>
Unit 1	Basic Concepts and Concept of Evolutionary Perspective on Human Growth	11
Unit 2	Stages of Growth and Growth Patterns	23
Unit 3	Methods of Studying Growth	40
<b>BLOCK 2</b>	<b>HUMAN GROWTH AND ECOLOGICAL FACTORS</b>	<b>51</b>
Unit 4	Bio-cultural Factors Influencing Growth Patterns and Variations	53
Unit 5	Adaptation to Environmental Stress	62
Unit 6	Ecological Rules	74
<b>BLOCK 3</b>	<b>NUTRITIONAL ANTHROPOLOGY</b>	<b>89</b>
Unit 7	Assessment of Nutritional Status	91
Unit 8	Concept of Balanced Diet	103
Unit 9	Impact of Malnutrition	117
<b>BLOCK 4</b>	<b>BODY COMPOSITION, HUMAN PHYSIQUE AND SOMATOTYPING</b>	<b>127</b>
Unit 10	Human Body Composition	129
Unit 11	Somatotyping and Human Physique	142
Unit 12	Human Physique	157
<b>PRACTICAL MANUAL</b>		<b>169</b>
<b>SUGGESTED READINGS</b>		<b>193</b>



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## **COURSE INTRODUCTION**

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Biology and culture are two important nuclei in Anthropology. In Biological Anthropology (previously called as physical anthropology), there are three major fields: Human Population Genetics, Human Growth and Development and Dermatoglyphics. The initial phase of the Discipline was focused on comparative anatomy, somatometry, craniometry, somatoscopy, osteology and osteometry of human. All these aspects were included in Human Growth and Development and this emerged as most important dynamic field in biological anthropology. Growth and development are fundamental to all living organisms. Interestingly both of them almost happen concurrently, they are inadvertently considered as single biological phenomenon. However, the fact is they are not indistinguishable but qualitatively different processes. In most elementary terms growth broadly refers to increase in overall size of the body whereas development stands for increase in complexity and functional ability. The process of growth commences with the fertilized ovum and goes on up to adulthood when an individual attains his/her adult size, shape and maturity. These two are basic processes that shape an individual's progression from birth to adulthood. Nevertheless, some biological changes continue even beyond adult life till death of an individual. Prenatal, infancy, childhood, adolescence, adulthood and senescence are different phases that are witnessed in the process of human growth. One should know how the human grow; react in different environmental zones, what one studies in human growth, factors affecting human growth and many more aspects which are the essential in studying human growth and development.

The anthropological approach to human growth and development assimilate research about people from all parts of the world, from past as well as current cultures. The study of growth and development is very important in biology as it also throws light on the mechanism of evolution. It is to be made clear here that growth is predetermined by hereditary components, but could be influenced by several exogenous agencies. Similarly development of certain organs may have hereditary basis but manifestation may be influenced by external factors. As just mentioned, 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. 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.

The studies concerning the human body in relation to the physical surrounding have been carried out to improve the clothing size may be regarded as remarkable contribution in this field. The application of human growth and development is applicable in all spheres of life when human body is used for any purpose. Human Growth and Development gives you an idea for research dealing with ethnic groups, human population and tribal population etc. so that you can apply your learning for the welfare of the society.

With this background, the present course on Human Growth and Development has four thematic blocks covering the important features of Human Growth and Development. The first block comprising of three units caters to the Fundamentals of Human Growth. Unit 1 deals with the basic concepts and concept of

evolutionary perspective on human growth whereas in unit 2 various stages of growth and growth patterns are described. Unit 3 discusses the different methods of studying growth covering merits and demerits of each method. In the second block Human Growth and Ecological Factors (Unit 4 through 6), a balanced coverage on factors influencing growth has been presented with unit 4 dealing with the bio- cultural factors influencing growth patterns and variations. Human is highly adaptable that why we find them present all over the globe. Unit 5 on adaptation to environmental stress and unit 6 on ecological rule is linked to it.

Nutritional Anthropology the theme of third block comprises three units (Unit 7 through 9). In this block varied areas regarding nutrition are covered, right from assessment of nutritional status in unit 7, to unit 8 detailing concept of balanced diet and analysing the impact of malnutrition in unit 9.

In the last block of this course (Unit 10 through 12), a detailed description on the Body Composition, Human Physique and Somatotyping have been presented, with Unit 10 offering a detailed description on human body composition. In unit 11 you will learn about somatotyping and human physique and unit 12 is devoted to human physique.

The practical manual on Human Growth and Development broadly comprises of five sections. In the first section growth status is assessed using somatometry. Second section is about assessment of chronological age., that of percentile, z-score, height for age, weight for age and BMI for age. Then a very important issue in current scenario obesity assessment is dealt in Section 3 by assessing BMI, Body Fat %, Conicity Index, Body Adiposity Indices and Regional Adiposity Indices by waist circumference, waist-hip ratio and weight - height ratio. Section 4 is on Estimation of Body Composition using fat percentage and muscle mass with skinfold thickness and Bioelectric Impedance. In the last section Nutritional Assessment is taken up using Anthropometric Indices and Dietary Methods. This practical manual will enable you to understand the application of various metric observations of human body.



**BLOCK 1**

**FUNDAMENTALS IN HUMAN GROWTH**

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# UNIT 1 BASIC CONCEPTS AND CONCEPT OF EVOLUTIONARY PERSPECTIVE ON HUMAN GROWTH\*

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## Contents

- 1.0 Introduction
- 1.1 Human Growth, Development, Differentiation and Maturation
- 1.2 Concept of Evolutionary Perspective on Human Growth
- 1.3 Evolution of Human Growth
- 1.4 Mammalian Growth
- 1.5 Primate Growth Patterns
- 1.6 Unique Patterns of Human Growth
- 1.7 Philosophy of Human Growth
- 1.8 Summary
- 1.9 References
- 1.10 Answers to Check Your Progress

## Learning Objectives

After going through this unit, you will understand

- difference between human growth, development, differentiation and maturation;
- basic concept of evolutionary perspective on human growth;
- mammalian growth;
- primate growth patterns; and
- unique patterns of human growth and philosophy of human growth.

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## 1.0 INTRODUCTION

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Growth as per British English refers to the progressive development of a living being or part from an earlier stage to its maturity including increase in size and development as a series of changes by which an individual embryo becomes a mature organism. In simple terms growth is increase in size of various organs and parts of body by multiplication of cells and intercellular components during a period commencing from fertilization to maturity. Human growth in physical anthropology enjoys an enviable position since the discipline seeks to understand the meaning of the striking range of variability which confronts him; he is constantly faced with the importance of the processes of physical growth and development.

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\*Contributor: Professor Satwanti Kapoor, Retd. Department of Anthropology, University of Delhi, Delhi

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## 1.1 HUMAN GROWTH, DEVELOPMENT, DIFFERENTIATION AND MATURATION

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Growth is fundamental characteristic of all living organisms. It is the physical change and increase in size and it can be measured. Indicators of growth include height, weight, bone size and dentition. Development is an increase in the complexity of function and skill progression.

It is a capacity and skill of person to function. Growth and development are independent, interrelated processes e.g. muscles, bones and nervous system of an infant must grow to a certain point before, the infant sits up or walk. Growth is an intense biological process during the infancy stage of human life, including nine months of prenatal life. While growing, the individual matures as well. Growth means the increase in the size of the various parts and organs of the body by multiplication of cells and intercellular components during the period commencing from fertilization to physical maturity.

There are three major processes involved with the changes in size:

- ❖ hyperplasia- an increase in cell number;
- ❖ hypertrophy- an increase in cell size; and
- ❖ accretion- an increase in intercellular substances.

All these processes occur during growth, but the predominance of one or another process varies with different life stage.

According to Watson and Lowrey (1967) “growth means an increase in the physical size of the whole or any of its parts.” Juan Comas defines it as the objective manifestation of hypertrophy and hyperplasia of the organism constituent tissues determined by post natal body size. Development refers to the increase of functional capacity in perfect form resulting from production of specialised tissues from unspecialised ones. Development is a characteristic feature of living matter that carries it through the process of progressive evolution to a state of perfect function (Comas, 1960). According to Hurlock (1941) development is the change in progressive series which are orderly and coherent and which lead to maturity. According to Watson and Lowrey (1967) growth may mean increase in physical size of the whole or any of its part which may be measured and development indicates an increase in skill and complexity of function.

Maturation refers to the tempo and timing of progress toward the mature biological state. Variation in progress over time implies variation in rate of change. It should be evident that growth and maturation are closely related. The terms growth and maturation are often used in conjunction with the term development. The latter denotes a broader concept often used in two distinct contexts. The first context is biological, and here development is the differentiation of cells along specialized lines of function. This mainly occurs early in prenatal life when tissues and organ systems are being formed. The development of function continues during post-natal life as different systems of the body become functionally refined. The second context is behavioral and relates to the development of competence in a variety of interrelated domains as the child adjusts to his or her cultural milieu– the amalgam of symbols, values, and behaviours that characterize a population.

### Check Your Progress 1

- 1) Differentiate between growth and development.

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## 1.2 CONCEPT OF EVOLUTIONARY PERSPECTIVE ON HUMAN GROWTH

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Our existing knowledge about human growth is mostly obtained from the research on animals. This is due to ethical issues associated with experimental research involving human beings. Another reason is the evolutionary history that connects all living organisms, meaning that growth processes occurring in non-human animals are often but not always, identical or similar to those occurring in people. The discovery of the genomic homeobox gave insights about powerful genetic evidences for the common evolutionary origin of animal development (Mc Ginnis et al., 1984). A homeobox is a DNA sequence with about 180 long base pairs. It has codes for 60 amino acids segment of proteins, regulating the patterns of development. All eukaryotic genomes have the presence of genes containing homeoboxes which are associated with cell differentiation and segmentation of the body parts during the process of embryological developments. Identification of PAX-6 gene became another evidence for common evolutionary origin which is reported to be the master control gene for eye development in those with one or more eyes (Halder et al., 1985; Callaerts et al., 1997; Gehring, 1998). This brings forth a new hypothesis about the common evolutionary origin of the eye.

Biological evolution is the common process of changes which take place in the genetic traits over successive generations in order to adapt to their environment. During these processes, adaptation is the key evolutionary process wherein the fittest survive through natural selection before the reproductive maturation and by the differential fertility and mortality of the naturally selected organisms. The overall mechanism i.e. genetic, genomic and phenotypic adaptation of the organisms to adapt with the environment enhance the survival of the organism till the reproductive age thereby resulting in an increase of production of healthy offspring and increase in their frequency in a population. The unique stages of event of human growth and development evolved because they conferred reproductive advantage to the species.

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## 1.3 EVOLUTION OF HUMAN GROWTH

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Biologists and anthropologists have proposed a number of taxonomic schemes for classifying the uniqueness of *Homo sapiens*. Lovejoy (1981) has suggested five characteristics of human as defining features: bipedalism, a large neocortex, reduced anterior dentition with molar dominance, material culture and unique sexual and reproductive behaviour. The development of each of these characteristics can be seen in the ontogenetic unfolding of the human patterns of

growth and development. For instance, bipedalism is made possible by differential growth of the legs and pelvis versus the arm and shoulder girdle. Our unique sexual behaviour results, in part, from our prolonged childhood, delayed maturation and species specific neuroendocrine physiology. The human pattern of endocrine physiology results in the menstrual cycle among women, the continuous sexual receptivity of both sexes, and the development of our secondary sexual characteristics. These are some of the unique features of *Homo sapiens* and human growth. Though this characteristic sets us apart from all other species, they have their origin in evolutionary history. Hence we share many basic growth patterns with other species, but differ through some special evolutionary developments.

Thus qualitative and quantitative differences exist between human growth curves and their non-human counterparts. Unlike the non-human curve of growth, the human growth curve cannot be modelled with a single mathematical function, that is, it is not completely differentiable over its length. The distance curve requires at least two functions, one for the pre-adolescent segment and one for the adolescent segment (Shohoji and Sasaki, 1984). The velocity curve requires at least three mathematical functions for the:

- ❖ infantile segment (birth to about four years),
- ❖ childhood segment (from about 4 years to the beginning of the adolescent spurt), and
- ❖ adolescent spurt (Bogin 1980; Karlberg 1985).

These mathematical features of human growth are unique, but they have their origin in the patterns of growth followed by mammals, in general, and the primates, in particular.

**Check Your Progress 2**

2) What are three mathematical functions required by the velocity curve?

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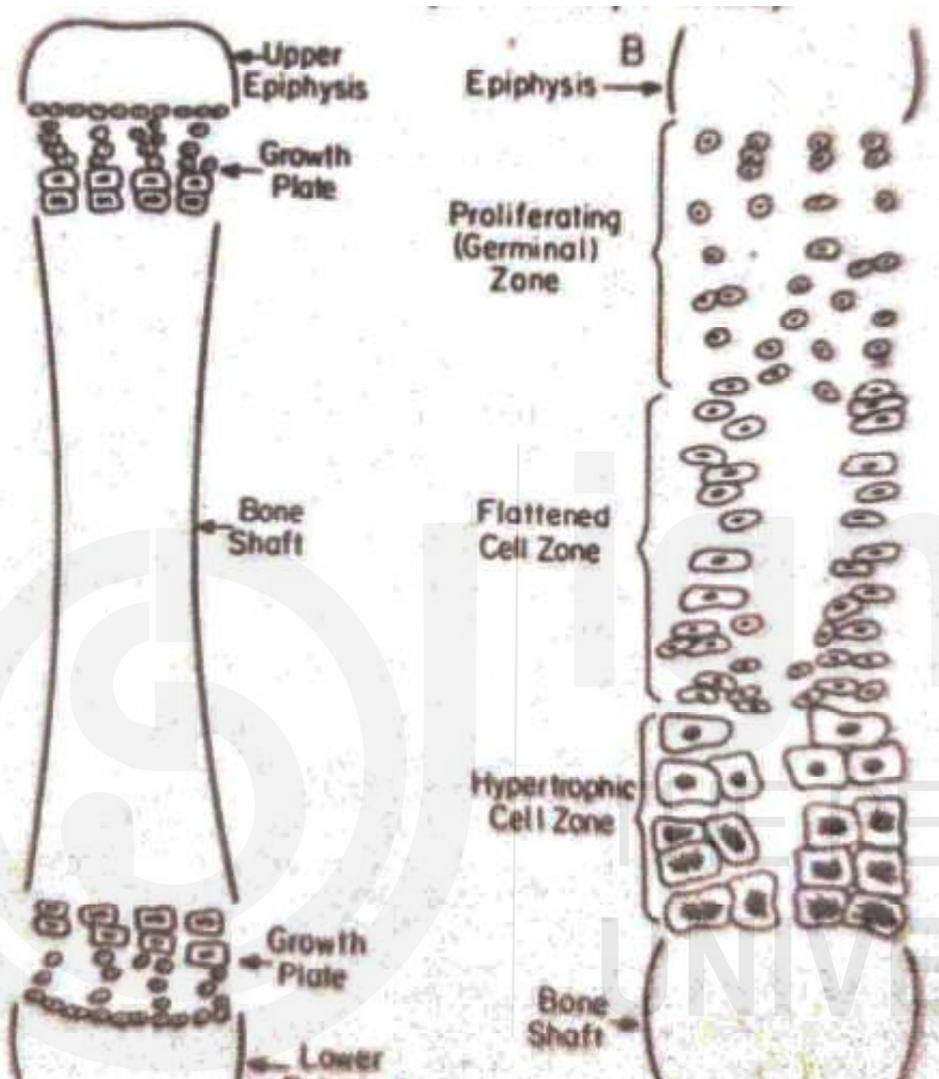
**1.4 MAMMALIAN GROWTH**

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Some reptiles and most of the mammals have put an end to unlimited growth through the evolution of the cartilaginous growth plate system.

Figure 1.1 shows typical mammalian long bone, its diaphysis, epiphysis and growth plate. The growth plate separates the growing part of the bone from the rigid part. This allows bone fully to perform its function throughout growth and also allows for the cessation of growth. The latter is necessary for terrestrial animals that must support their own body weight without the help of water or any other buoyant medium. An end to growth is also necessary for terrestrial mammals that depend on rapid and flexible movement to find food and avoid

predators. The largest terrestrial mammals, the Proboscidea (elephants and the allied extinct mammoths and mastodons), may have reached the limits of size for land animals of their class. The limbs of these animals are used almost entirely for support of the body and locomotion. The evolution of a flexible muscular appendage and the trunk serves the function of a limb for food gathering and environmental manipulation.



**Fig. 1.1: A-Diagram of limb bone with its upper and lower epiphysis**

**B- Diagrammatic enlargement of the growth plate region**

*Source:* Adapted from Tanner (1978)

Another fundamental aspect of mammalian bone is its remodelling during growth. As a bone grows in length or size, its surfaces must be reworked so that its characteristic shape and function can be retained. According to Enlow (1976), in a long bone this remodelling is achieved by removing old ossified bone tissue from the periosteal (outer) surface and adding new bone tissue to the endosteal surface (surrounding the hollow or sponge like core). Mammals achieved the efficient, rapid and flexible mobility that they require via bone remodelling, the cessation of growth of the skeleton and evolutionarily derived functional alterations in the articulation of limb bones (Roemer 1966).

The evolution of the placenta removed some of the limitations to prenatal growth, including both growth in size and length of gestation. The prenatal growth and

gestation of non-placental animals such as most reptiles, birds, monotremes (the platypus and echidna) and most marsupials (e.g. opossums and kangaroos) is limited by the need to package foetal nutrients in the yolk sac and foetal waste products in a separate sac called allantois. In contrast the placenta, provides for foetal nutrition, respiration and the removal of metabolic waste continuously throughout the gestation. The critical advance in the biology of placental mammals is that the foetus can develop and grow to an advance stage protected and well-nourished in the uterus.

The young mammals' capacity for learning and the infant growth period that is its basis, relates to the special mammalian characteristics, namely the ability of each offspring to help insure its own survival to reproductive age. The way mammals accomplish this is through the growth of relatively large brains and the flexibility in behaviour that these large brains allow. The evolutionary record show that the mammalian brain has undergone repeated selection for increase in size and complexity. Mammals have also evolved more complex and functionally diversified brain structures like the mammalian neocortex and its neurologically distinct regions (the motor-sensory region, the auditory and visual regions, etc). The evolution of the placenta is directly related to the evolution of larger, more complex brains and greater learning abilities. The placenta is the organ that constantly supplies oxygen and nutrients to the constantly developing fetal brain and allows that brain to develop to an advanced stage before birth. Each higher mammalian group has a brain that is relatively larger than expected or its body size. Humans have one of the largest brains to body weight ratios, perhaps the most complex and active brain of any mammal, as well as the most efficient placental system of any primate. The infant primate grow more slowly than most other mammalian new borns, therefore, is dependent for a longer time on this intimate relationship with its mother. Infant dependency extends the period of growth, development and protection, and also increases the opportunity for the infant to learn survival skills by observing successful maternal behaviours.

**Check Your Progress 3**

3) Complete the sentence "The critical advance in the biology of placental mammals ....."

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**1.5 PRIMATE GROWTH PATTERNS**

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Primates have a juvenile stage of development which occurs between infancy and adulthood. Most non-primate mammals grow in size and develop towards sexual maturity along a smooth and continuous path from birth to adulthood, with no biologically or mathematically discernible alterations in growth trajectory. The old world monkeys, apes and human follow a pattern of growth that differs from most other mammals in two ways. The first is that sexual development is deferred until a time well after the infancy period of postnatal growth takes place.

This period of delayed growth is the primate juvenile growth period. The second difference is that neurological development, especially growth of the brain is about 90 percent complete before sexual maturity is achieved. Laird (1967) reviewed the growth of the Rhesus monkey, chimpanzee and human. She found that monthly weight increases in the male rhesus monkey followed two separate growth curves, the first from birth to 22 months and the second from 23 months onwards. Laird found that the growth of chimpanzee also required two mathematical functions to describe its course from birth to maturity. The earlier phase of growth was best approximated by a linear function from birth to six years. This was followed by an adolescent phase that was modelled by a curvilinear function. Male and female chimpanzees followed the same pattern of growth from birth to adulthood. During the first phase the amount of growth achieved by males and females was identical, but during adolescence, sexual dimorphism in size became well marked; male weight growth deviated from the fitted curve than female's growth. Laird (1967) found that the velocity curve of human growth required three mathematical functions to model its course, a conclusion also reached independently by Bock and Thissen (1976), Bogin (1980) and Karlberg (1985). The need of third function is one aspect of human growth that makes it unique, even among primates. Human add childhood as a period of growth between infancy and juvenescence (the start of the juvenile growth period), thus remaining dependent upon adult caregiving for a relatively and absolutely longer time than any other primate. The other key differences between non-primates and primate growth involve the relative rates of growth of the body, the brain and the reproductive system.

#### Check Your Progress 4

- 4) The old world monkeys, apes and human follow a pattern of growth that differs from most other mammals in two ways. Enlist them.

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## 1.6 UNIQUE PATTERNS OF HUMAN GROWTH

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The prolonged delay in human growth due to the evolution of childhood period growth is one feature of the human growth curve that distinguishes it from all others. The deferred onset of sexual maturation, which does not begin until the last third of the growth period, shortens the time available for the achievement of the adult body size. Mann (1968, 1975) and McKinley (1971) analysed the South and East African Australopithecus remains and found that fewer than 50 percent of these extinct hominids lived past 20 years of age and only 15 percent lived to age 30. Sacher (1975) estimated that *A. africanus* reached sexual maturity at 10 years (an average age for male and females). Thus as Washburn (1981) pointed out, there was relatively little time between the end of childhood and death for a slow process of adolescent growth to occur. The evolutionary result of the competing selective pressure for a prolonged childhood period of growth, learning, and socialization versus sufficient time during adulthood for

reproduction and parental care of offspring is the well-marked phase of rapid growth at the end of childhood known as the adolescent growth spurt. This is a regular feature of growth of all human children. There are several empirical evidences and evolutionary consideration which confirms that the human adolescent growth spurt is a unique characteristic. Watts and Gavan (1982) found that simple plots of height or weight or age did not reveal growth spurt in either the rhesus monkey or chimpanzee. This stands in contrast to the human case, where simple graphical methods of analysis reveals the adolescent growth spurt in virtually all children.

The acceleration in the growth of muscle mass or bone length that occurs during the puberty of non-human primates is correlated with the endocrine changes that occur during reproductive maturation. Growth at human puberty is due to similar endocrine changes (Prader 1984), but the human adolescent spurt in the rate of skeletal growth and the rate of growth in weight are large compared to the small change in the rate of growth of the skeleton of non-human primates, another qualitative difference between human and non-human adolescent growth.

To sum up, we may say that there are three major differences between human and non-human primate growth:

- ❖ The residual growth potential of the non-human versus the human primates at adolescence,
- ❖ The sensitivity of different body tissues to growth promoting stimuli, and
- ❖ Sex differences in the expression of growth spurt at adolescence.

The monkey, ape and human all experience a delay in sexual maturation and a prolongation in growth. In the humans, the delay is both relatively and absolutely greater than in the monkey or ape (Laird 1967). In addition to this, humans also have a markedly increased potential for growth in height and weight during adolescence. This growth potential is likely to be regulated more by the sensitivity of neuroendocrine receptors and post receptors (i.e. biological tissues) to growth stimuli than by the rate or amount of production of the stimuli (e.g. hormones) themselves. The lack of linear association between testosterone concentration and growth velocities in skeletal and non- skeletal tissues of chimpanzee and human shows this. The difference in cellular sensitivity to growth stimuli between non-human and human primate growth are probably controlled at the genetic level, but are not the result of the evolution of new structural genes. Rather, control lies in the regulatory genes that initiate and terminate each of the distinct periods of growth and control their duration (King and Wilson 1975).

**Check Your Progress 5**

5) What are the three major differences between human and non-human primate growth?

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## 1.7 PHILOSOPHY OF HUMAN GROWTH

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Non-human primate models are used to study human growth because of similarities in anatomy and physiology between the species. Also, there is an assumed evolutionary continuum between the living primate species- *Macaca mulatta* (rhesus monkey), *Pan troglodytes* (chimpanzee) and *Homo sapiens* (human being). There is an evolutionary connection relating these species, however, the living monkeys, apes and humans, each have a separate evolutionary history. Cercopithecines (old world monkeys) and hominoids (apes) separated some 20 million years ago and the hominoid-hominid (apes-human) split occurred at least six million years ago. There is no evolutionary reason to expect that the pattern of growth of these three divergent and ecologically distinct species should be identical or even similar. As Gavan (1971) observed, chimpanzee post natal growth begins with an initially high rate which decelerates smoothly as size increases, but it is well known that human growth is characterised by a growth spurt. Some changes must have occurred in human growth since we and chimpanzee have had a common ancestor.

The notion of an evolutionary continuum, a 'great chain of being' (Lovejoy 1936) is a popular cultural construct in western society. In its original usage, it implied, erroneously, that all living creatures, from amoeba to human, form a living evolutionary sequence from the simplest to the most complex creature. We now understand that humans are not the culmination or the goal of evolutionary history. We are just one of more than two million animal species alive today, each the end product of his own history and each with its own unique place in nature. Gould suggests that the major difference between human and non-human primate growth is that human mature sexually while still in an infantile or child- like stage of physical development. Compared with the chimpanzee, we are neotenus or fetalised in our body growth and in our physical features. The infant chimpanzee exhibit many features of the adult human: a large rounded cranium, flat face, and erect posture. The adult chimpanzee exhibits a prognathic face due to hypermorphic growth of jaws and semi erect posture due, in turn, to its knuckle walking and brachiating mode of locomotion. On the other hand adult humans are paedomorphic, that is, retaining as adult the characteristics of the fetal, infantile and childhood period of development.

### Check Your Progress 6

- 6) What are the features exhibited by infant chimpanzee?

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## 1.8 SUMMARY

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This unit takes a life history approach to the study of human growth and development. The human life cycle however has been identified with six stages namely: infancy, childhood, juvenile, adolescence, adulthood and post-

reproductive stages of life. The philosophy of human growth and development that emphasize the progressive appearance of new biological and behavioural traits is more satisfying empirically, and intellectually, than a view of development that emphasizes growth retardation and the permanency of childhood. An acceptable philosophy must also acknowledge the mammalian and primate origin of the human patterns of growth. Combining each of these ideas into a holistic conceptualisation of growth allows one to understand the quantitative differences in development between species and the qualitative uniqueness of the human growth patterns.

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## 1.10 ANSWERS TO CHECK YOUR PROGRESS

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- 1) Growth is a fundamental characteristic of all living organisms. It is the physical change and increase in size and it can be measured. Indicators of growth include height, weight, bone size and dentition. Development is an increase in the complexity of function and skill progression.
- 2) The three mathematical functions required by velocity curve are:
  - a) infantile segment (birth to about four years)
  - b) childhood segment (from about 4 years to the beginning of the adolescent spurt)
  - c) adolescent spurt
- 3) The critical advance in the biology of placental mammals is that the foetus can develop and grow to an advance stage protected and well-nourished in the uterus.
- 4) The old world monkeys, apes and human follow a pattern of growth that differs from most other mammals in two ways:
  - i) sexual development is deferred until a time well after the infancy period of postnatal growth takes place. This period of delayed growth is the primate juvenile growth period.
  - ii) neurological development, especially growth of the brain is about 90 percent complete before sexual maturity is achieved.
- 5) The three major differences between human and non-human primate growth are:
  - 1) The residual growth potential of the non-human versus the human primates at adolescence.
  - 2) The sensitivity of different body tissues to growth promoting stimuli.
  - 3) Sex differences in the expression of growth spurt at adolescence.
- 6) The infant chimpanzee exhibit many features of the adult human: a large rounded cranium, flat face, and erect posture.

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## UNIT 2 STAGES OF GROWTH AND GROWTH PATTERN

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### Contents

- 2.0 Introduction
- 2.1 Understanding Growth and Development
- 2.2 Stages of Growth
- 2.3 Prenatal Growth
- 2.4 Postnatal Growth
  - 2.4.1 Neonatal Stage
  - 2.4.2 Infancy Stage
  - 2.4.3 Childhood
  - 2.4.4 Adolescence
  - 2.4.5 Maturity or Adulthood
  - 2.4.6 Senescence
- 2.5 Normal Growth Curves Pattern
- 2.6 Normal Growth Variations
  - 2.6.1 Canalization
  - 2.6.2 Catch up Growth
  - 2.6.3 Catch down Growth
- 2.7 Growth Curves and Ethnic and Gender Differences
- 2.8 Secular Trend
- 2.9 Summary
- 2.10 References
- 2.11 Answers to Check Your Progress

### Learning Objectives

Once you have read this unit, you will:

- be able to understand the concepts of growth and development;
- be acquainted with stages of growth;
- appreciate normal growth curve pattern, normal growth variation or variation from normal growth; and
- get to know about ethnic and gender differences in growth curves.

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## 2.0 INTRODUCTION

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Primates generally have a slow reproductive turnover and drawn-out life histories. As part of this pattern, the pace of growth from birth to adulthood is retarded and in monkeys, apes and humans, at least, it is possible to recognize special features of the growth curve associated with the attainment of sexual maturity [(puberty), (characteristics were once supposed to be unique to humans but other primates were later found to have them as well)]. The distinctive form of the human growth

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curve was first established in the eighteenth century. Sexual differences in the curve, originally denied, were confirmed in the 1880's, but the evolutionary significance of its shape only became clear after 1950 (Jaiswal, 2013).

The velocity, speed, or pace of development mirrors the kid's state at a specific time being than does real tallness, which relies generally upon how much the child has developed all through life. The blood and tissue concentrations of those substances that change with age are subsequently bound to go with the speed or velocity than the distance curve. In certain conditions, acceleration of growth rather than its velocity may reflect physiological events; the increase in secretion from the endocrine glands at adolescence, for example, is seen most clearly in an acceleration of growth.

The velocity of growth in height decreases from birth onwards, yet, this, decline or decrease is interfered or interrupted shortly before the end of the growth period. At this time, from 13 to 15 year of age in the boy, there is a marked acceleration of growth-the adolescent or pubertal growth spurt. A slight increase in velocity, the mid growth spurt, may also occur between about 6 and 8 years, providing a second peak on the general velocity curve. After maturity the matured boy or girl becomes the important member of the society.

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## 2.1 UNDERSTANDING GROWTH AND DEVELOPMENT

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Understanding the growth and development of the human organism requires an understanding of nature and nurture, and the complex interplay between the two. The terms growth and development are actually two different terms having separate meanings, but most of the time they are used interchangeably. This creates a lot of confusion. Terminologically, growth means increase and enlargement of the body or some parts of the body, i.e. the cases where the body becomes heavier, larger, longer etc. It is a change in the organism which can be observed and measured in the physical sense denoting an increase in size, length, weight, proportion etc. Therefore, all changes in quantitative form which could be objectively observed and measured come into the domain of growth. On the other hand, development refers to the qualitative changes. These are the changes in kind, structure or organization- a complex process of integrating many structures and functions, which may not be observable or measureable outwardly. Thus, growth can be one of the components of development process or development in its quantitative aspect can be termed as growth.

### Check Your Progress 1

- 1) Write short notes on understanding Growth and Development.

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## 2.2 STAGES OF GROWTH

The stages or phases of growth have been classified in different ways or manners by different scholars. A simple classification of the postnatal period includes four stages like early childhood, later childhood, adolescence and puberty; or, early childhood, middle childhood, late childhood and adolescence.

A detailed classification, proposed by R.L. Scammon as early as in 1930, is given below to have a good idea of the stages growth.

**Table 2.1: Stages of Growth**

Prenatal	Ovum		(first 2 weeks)		
	Embryo		(from 2 to 8 weeks)		
	Fetus		(from 2 to 10 lunar months)		
Postnatal	Infancy	Neonatal	(first 2 weeks)		
		Infancy	(from 2 weeks to 1 year)		
	Childhood	Early		(from 1 to 6 years)	
		Middle		(from 6 to 9 or 10 years)	
		Late	Boys		(from 9-10 to 13-16 years)
			Girls		(from 9-10 to 12-15 years)
	Puberty	boys		(around 14 years)	
		girls		(around 13 years)	
	Adolescence	boys		(from 14 to 20 years)	
		girls		(from 13 to 18 or 20 years)	
	Maturity			(from 18-20 to 60 years)	
Senility			(after 60 years)		

*Source:* Scammon, 1930

Thus, the two major periods of growth are prenatal and postnatal. This is true not only for human but also for all placental mammals. We are not going to follow strictly this classification of Scammon while discussing the stages of growth. Of the two major periods of growth, first, we are going to have some idea about the prenatal period, and postnatal period will be discussed under five subheads, namely, infancy, childhood, adolescence, maturity and senescence.

### Check Your Progress 2

2) Name the major periods of growth.

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## 2.3 PRENATAL GROWTH

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Prenatal development includes all the changes that take place in the womb of the mother. Therefore it is also called “intra-uterine development” where the uterus is the internal environment for growth.

Prenatal development covers the period from fertilization to birth. It comprises of three distinct stages:

- ❖ The period of the zygote: i.e. from fertilization to end of two weeks.
- ❖ The period of the embryo: i.e. from 2 weeks to 2 lunar months.
- ❖ The period of the fetus: i.e. from end of 2<sup>nd</sup> months till birth.

Although the velocity of growth in body length is greater at birth than at any later period, in fetal life the velocity is greater still. Its peak is reached at about the eighteenth week of postmenstrual age (Age in the fetal period is typically figured from the first day of the last feminine or menstrual period—a normal of about fourteen days i.e. 2 weeks preceding genuine prior to actual fertilization—but is usually the only easily located landmark of pregnancy).

Growth in fetal weight follows a similar general example, then again, except that the peak velocity is arrived at later, usually at the thirty-fourth postmenstrual week. From about 36 weeks to birth at 40 weeks, the pace or rate of growth eases or slows down, maybe in light of the fact that the space accessible in the uterus is getting completely involved or becoming fully occupied.. The growth of twins hinders prior when their joined or combined weight is approximately the weight of 36 week singleton fetus. Birth weight and birth size reflect the maternal environment more than the child’s genotype and the hindering component empowers a genetically large child or hereditarily huge kid creating in the uterus of a small mother to the delivered successfully. Directly after birth, the growth rate increases again, particularly in genetically large children, and the rate of weight gain reaches its peak at the age of approximately 2 months.

The velocity of growth in length is not very great during the first 2 months of fetal life, the period of the embryo. During this period, there is differentiation (‘regionalization’) of the originally homogeneous fetus into regions such as the head and arms, and histogenesis, the differentiation of cells into specialized tissues such as muscle or nerve. At the same time, each region is moulded, by differential growth of cells or by cells migration, into a definite shape. But the major part of it is completed by the eighth postmenstrual week and by then the embryo has assumed a recognizably human appearance compared and that of the child, is expected generally to cell multiplication. The proportion of cells going through division turns out to be less as the fetus gets elder, and hardly any, new muscle cells or nerve cells (aside from neuroglia, the cells surrounding the neurons themselves) appear after the sixth month of fetal life (Jaiswal, 2013).

The muscle cells and nerve cells of the fetus contrast in appearance from those of the child or adult. Both have almost no cytoplasm around the core. In fetal muscle, there is more intercellular substance and a lot higher extent of water than in the developed muscle. The later fetal and postnatal development of muscle comprises of developing the cytoplasm of the muscle cells; salts are fused and proteins shaped. The cells become greater the intercellular substance generally vanishes, and the convergence of water diminishes or decreases.

This cycle proceeds with effectively up to around 3 years old and gradually from that point; at youth, it quickly accelerates once more, especially in boys, as more substances are incorporated into the fibers under the influence of androgenic and growth hormones. During the same period there is an increase in the amount of DNA, indicating that further nuclei are appearing. In the nervous system cytoplasm is added, nucleoprotein bodies appear, and axons and dendrites grow. Hence, for most tissues, postnatal development is a time of advancement and broadening of existing cells, instead of the arrangement of new ones.

We can also simply explain the prenatal growth as...

The ovum of human at the time of conception is about 0.1 mm in diameter. During the first part or initial segment of this period (ovum), it resembles a homogeneous mass. During the embryonic stage, even though the pace of development is moderate, yet during this time the differentiation process or cycle in the mass to form various regions begins which later on give rise to various parts of the body. The cells are also differentiated into specialized tissues, like nerve, muscle. This process which gives definite shape to different parts is called morphogenesis. By the eighth week the embryo becomes childlike like in appearance. During fetus stage the pace of growth in length as well as weight is considerably high or impressively high. However, in length the peak is reached earlier than in weight. In the former it happens at about 18 weeks. From around 36 weeks the pace of growth of the fetus slows down generally due to the impact of the uterus of the mother (Jaiswal, 2013).

**Check Your Progress 3**

3) What are the main characteristics of Prenatal Growth?

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**2.4 POSTNATAL GROWTH**

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Postnatal growth starts from the time of birth upto adulthood or the time of maturity. Postnatal period is commonly divided into the following age period:

- ❖ Neonatal;
- ❖ Infancy or babyhood;
- ❖ Childhood;
- ❖ Adolescence;
- ❖ Adulthood/ Maturity;
- ❖ Senility or old age

**2.4.1 Neonatal Stage**

Neonatal stage begins with birth and ends when the infant is approximately two weeks old. It is the shortest of all developmental period.

It is a time when changes are very rapid. Many critical events can occur in this period: Feeding patterns are established, bonding between parents and infant begin. The risk for infections that may become more serious are higher and many birth or congenital defects are first noted.

### 2.4.2 Infancy Stage

Infancy lasts from two weeks to one year of life. It is true foundation period of life characterized by rapid change in bodily systems, psychological development and neuromuscular organization. During infancy stages growth is extremely quick or very rapid. More than 50 % of birth length and 200 % of birth weight occur during the first or primary year of life (Jaiswal, 2013).

From this period the rate of growth decreases sharply. It has been found that growth during infancy (during the first year of growth) is more rapid than at any other period during postnatal life. Birth length represents approximately 1/4 of the total stature against 1/8 in the adult. Cranial capacity is about 1/2 of the adult (Jaiswal, 2013).

Premature (baby born prior to 37 weeks gestation) babies have low birth weight. Low birth weight is associated with socio-economic conditions also (Jaiswal, 2013).

### 2.4.3 Childhood

Childhood usually ranges from the finish of infancy stages up to the beginning of adolescence. Infants in this way achieve childhood prior to arriving at adolescence.

On the basis of distance and velocity curves the pattern of growth during childhood can be obtained. That pattern may be regarded as the standard for a particular population and the growth pattern of the children of that population can be predicted accordingly. Both heredity and environment play their respective role in physical growth. Therefore, the hereditary growth potential of a child may be influenced by various environmental factors which include nutrition, state of health, socio-economic condition of parents, psychological well-being and the like. There are population variations in the pattern of growth (Jaiswal, 2013).

The early childhood is the period of eruption of deciduous or milk teeth. All milk teeth are erupted during this period. The permanent dentition also shows its beginning. The rounded body form continues to persist. The head in relation to the trunk continues to predominate, but in lesser degree. During this period the growth is relatively more in width than in height.

During the period of middle childhood (7 to 10 years) permanent teeth, though, not all, erupt and the rounded forms disappear. The size of head increases slightly. The linear growth of the body takes place rapidly. The thorax begins to become oval in transverse section. The waist line becomes definable. At about 7 and 8 years a nominal acceleration in the rate of growth occurs. It may be termed as mid-growth spurt.

The late childhood phase of growth stage starts from the prepubertal period and continues upto the time of puberty. Puberty normally occurs around 14 years (between 13 and 16 years) in boys and around 13 years (between 12 and 15

years) in girls. Sexual morphological differentiation normally begins during this phase. The rate of growth decreases during childhood. It becomes negligible towards the end of the late childhood phase. But a notable increase in growth velocity, known as the adolescent growth spurt, is observed which, however, is associated with the onset of sexual maturation (Jaiswal, 2013).

#### 2.4.4 Adolescence

Adolescence is the threshold of adulthood. It extends from twelve years to generally eighteen to twenty years i.e. it starts from the time of puberty and continues up to the onset of adulthood. The adolescence period extends from the time of puberty upto around 18 to 20 years (or 6 years following puberty). The acceleration of growth at adolescence causes many anatomical changes almost in all parts of the body. Sexual maturation takes place during this period.

This period may be divided into prepuberal and puberal phases. The pre-puberal phase lasts for about two years. During this time, the increase of weight is retarded. Height increases by the lengthening of the legs. The thorax becomes narrow; the trunk becomes short; legs and arms become long (Jaiswal, 2013).

During puberal period sexual organs are matured. The body proportions are changed. Secondary sexual characters appear. In girls the first menstruation marks the beginning of ovarian activity. But in boys it is difficult to ascertain precisely the time of maturation of the testes. The most obvious secondary sexual characters in girls are the development of breasts, appearance of auxiliary and pubic hair. In boys also pubic hair, beard and moustache show appearance. Moreover, the voice changes. In other words, differentiation in primary and secondary sexual characteristics or sexual qualities denotes the adolescence period (Jaiswal, 2013).

#### 2.4.5 Maturity or Adulthood

The term adult means grown to full size and strength or matured, Adults are therefore individuals who have completed their growth and are ready to assume their status in society as full grown individuals. The discontinuance or cessation of growth of stature is viewed as an indication or sign of maturity. Height ceases to grow when the long bones, *e.g.*, tibia, fibula etc., lose their capacity to increase in length. Usually, males attain the adult height at about 21 years of age and females at 18 years of age.

Another important sign of adulthood is reproductive maturity. During adolescence reproductive maturity begins, but not completed. The average girl is not capable of reproduction until 14 years of age or older, though onset of puberty may take place earlier. Because after menarche there is a period of one to two years of adolescent sterility, when ovulation does not occur. In case of boys also, though they begin producing sperm during puberal phase at about 14.5 years of age, their development is not complete. They still show more resemblances to the children than to the adults in respect of psychological and physiological conditions and also in physical appearance. On average adult males are heavier and taller than adult females (Jaiswal, 2013).

Adulthood is the longest period of the lifespan i.e. a period of more or less stability. Childhood and adolescence are the period of growing up whereas adulthood is the time for settling down. The period is further divided into:

- Early adulthood: it extends from the age of 18-20 years to 40 years.
- Middle adulthood: it extends from the age of 40 years to 60 years.
- Late adulthood or Senility: it extends from the age of 60 years to till death.

### 2.4.6 Senescence

After the active phase of the life-span, decline process starts resulting in an old age or senescence. After the prime period of adulthood senescence starts. The aging pattern shows great individual variation. The aging time also differs from person to person and society to society, because environment plays an important role. During this period numerous molecular and cellular changes happen. Organism changes are also there. These progressions or changes are quantifiable and can be depicted or described, yet these don't display a particular example any specific pattern or well-defined sequence. It appears there is no biologic arrangement or plan for aging / maturing process. A multi-causal mechanism is associated with this cycle.

The processes of growing old are scientifically studied in a special branch, called Gerontology. Because of aging the tissues do not renew and as a result cells show senile involution. The memory declines. Aged persons need more time to learn and to react. The speed of conduction in motor nerves shows a decline. Systolic blood pressure increases. Peripheral resistance and circulation time in the cardiovascular system show an increase. The range of accommodation of the eye lens declines. There is reduction of density of long bones and vertebrae, and therefore, height and sitting height show decrease. Arm span circumference of forearm and that of calf diminishes. Vital capacity and muscle tone declines (Jaiswal, 2013).

#### Check Your Progress 4

- 4) Explain in brief about Postnatal Growth.

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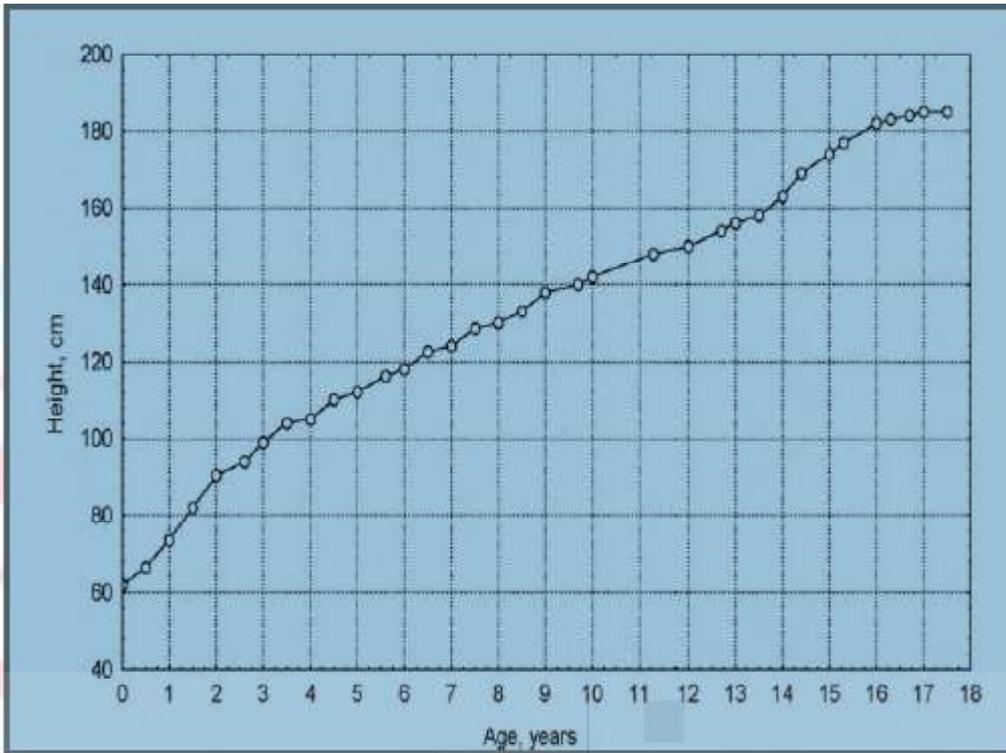
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## 2.5 NORMAL GROWTH CURVES PATTERN

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Growth is measurable, and therefore, anthropometry plays a very important role in the study of growth. The measurements or the values at successive ages are plotted in a graph to obtain growth curves. Usually two types of growth curves are drawn, namely Distance Curve and Velocity Curve.

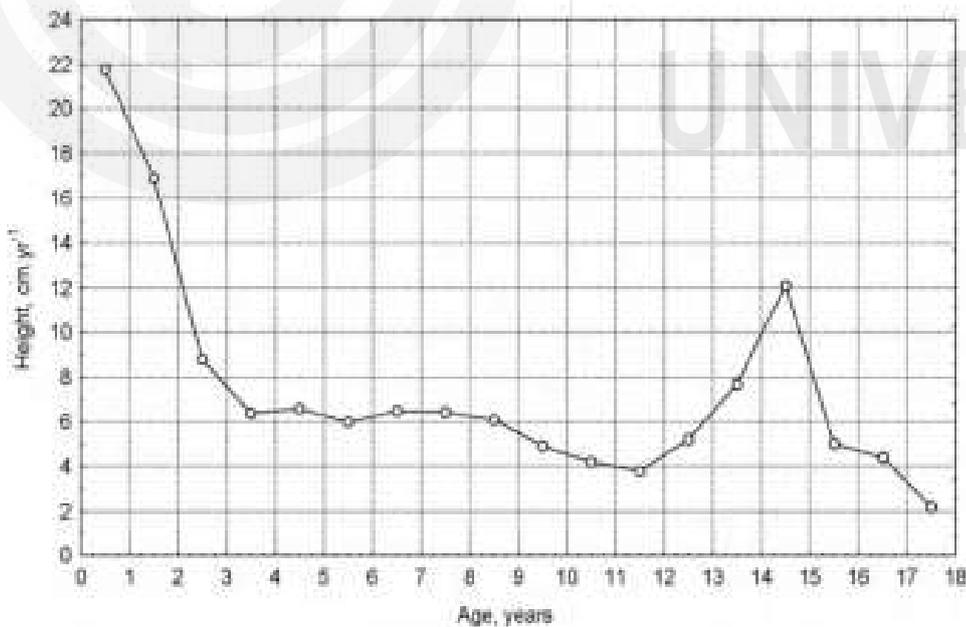
Growth may be considered as a form of motion. An object may move from one point to another covering a distance. This distance can be measured. Similarly, a part of the body grows from one age to the next. This increment can be measured and can be shown in a curve. This type of curve is called distance curve (Tanner, 1962).



**Fig 2.1: Distance Curve. Growth in height from birth to 18 years, 1759-77**

*Source:* Tanner, 1962

Again, during movement the object may not move at the same speed all through. In the same manner, the velocity or rate of growth may not be the same during different stages of growth. This can be obtained from velocity curve. In this connection it may be noted that different parts of the body do not grow at the same rate during different periods of growth (Tanner, 1962).



**Fig 2.2: Velocity Curve. Growth in height from birth to 18 years, 1759-77**

*Source:* Tanner, 1962

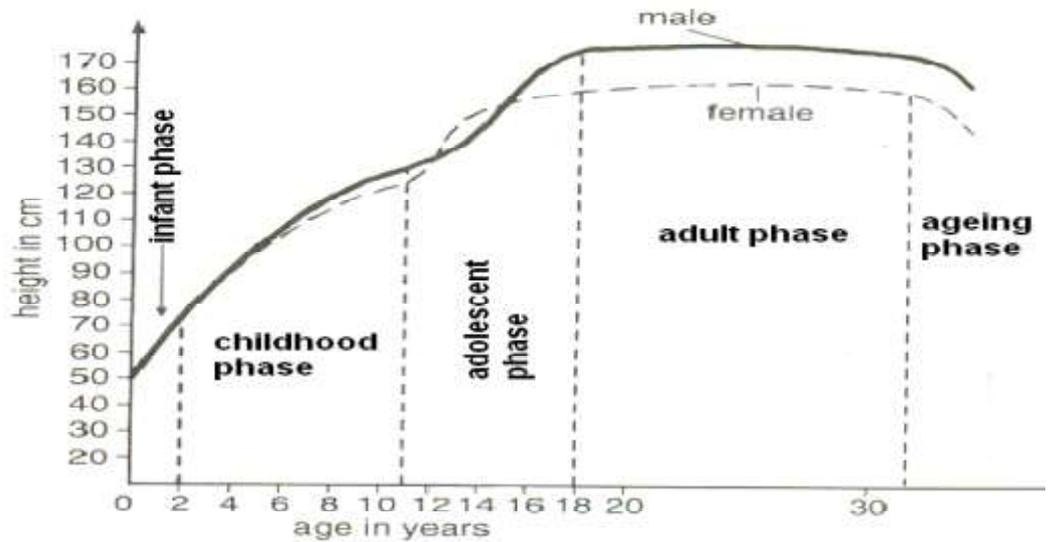


Fig 2.3: Growth Curve

Source: Cameron, and Lawrence. 2012

De Montbeillard measured the height or tallness of his son at regular intervals i.e every 6 months from his birth in 1759 until he was 18 years old in 1777. Richard E. Scammon from Department of Anatomy and the Institute of Child Welfare at the University of Minnesota plotted the diagram from these estimations or measurements and published his outcomes in 1927 in the American Journal of Physical Anthropology under the title of “The first seriatim investigation or study of human development”.

The non-human organisms share the basic sigmoid curve (s-shaped) of growth characterized by single peak. The initial period of maximum growth rate or acceleration is followed by period of deceleration in growth rate. The usual sigmoid curve is modified in case of human and is marked by two sigmoid curves, one in early life –the infant phase and the other in adolescent phase. They are separated by period of relatively slow growth rate during childhood. Subsequently, the growth curve has four particular distinct phases comparing to rapid growth in infancy, consistent or steady growth in childhood, quick or rapid growth during adolescence and moderate or 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. The above curve represents the general growth pattern for height, weight and some major organ systems (respiratory, digestive and urinary) of an individual, but different organs have their own pattern of growth (Verma, 2019; <http://epgp.inflibnet.ac.in/Home/ViewSubject?catid=1>)

**Check Your Progress 5**

5) Write short notes on Pattern of Normal Growth Curves.

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## 2.6 NORMAL GROWTH VARIATIONS

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Variations in normal growth represent alternative pathways that enable individual to achieve their growth potential. The general growth curve explains the growth of the body as whole and most of the system of body like skeleton system, respiratory system, digestive system, urinary system and circulatory system that includes heart and blood vessels. The S-shaped curve or sigmoid curve represents four phases of growth (Malina, et al. 2004):

- ❖ rapid growth in outset or infancy and early childhood
- ❖ steady yet constant or consistent growth during middle childhood
- ❖ rapid or fast growth during the adolescence
- ❖ slow and eventual cessation or possible suspension of growth after adolescence which proceeds or continues into third decade of life.

### 2.6.1 Canalization

Human growth and development is a complex phenomenon regulated by both, genetic and environmental factors. At conception, an individual obtains a genetic blueprint which determine the potential for achieving adult size and shape. In an unconstrained or neutral environment, individual would display an example or pattern of growth that is pretty more or less parallel or corresponding to the genetically predetermined trajectory. This phenomenon was described as “canalization” or “homeorrhexis” by British geneticist C.H. Waddington (1957). Notwithstanding, none of us has lived or been raised or brought up in a totally unconstrained environment.

### 2.6.2 Catch-Down Growth

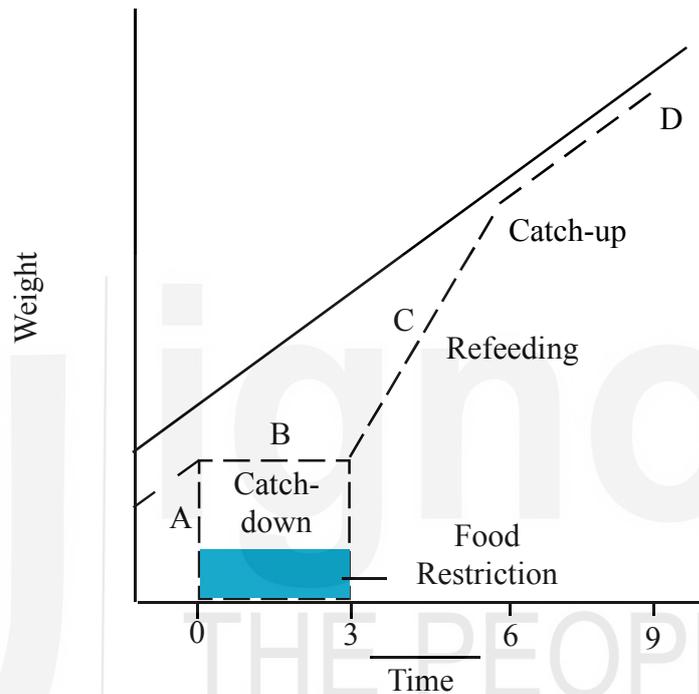
During the prenatal and postnatal life we are exposed to an array of adverse environmental factors (such as diseases, malnutrition etc) which influence the growth velocity. It either slows down, known as catch-down growth or in a more severe case would cease (Cameron 2012). The amount of deviation from the predetermined pathway depends on the frequency, duration and severity of exposure to the environmental factors. Slight exposure for short duration will cause minor change while considerable exposure for long duration in the velocity. The extent of influence is also determined by age and gender of the individual (Tanner 1978; Cameron 2012).

### 2.6.3 Catch-Up Growth

However, even after being pushed off the trajectories, there exists an ability to stabilize and return to a predetermined growth curve when conditions improve. During such recovery phase, initial growth velocity is above that of normally expected for children of his/her age or even of his/her skeletal maturity and decline as the child recovers. This rapid increase or quick expansion in growth velocity following a short term period or momentary time of starvation or illness was termed as catch-up growth by Prader et al. (1963).

The “catch-up” phenomenon also describes the relatively rapid postnatal growth observed in infants born with low birth weight due to intrauterine growth restriction. Catch-up growth is usually considered in terms of weight or height,

but it is important to consider the type of tissue deposited in the body. For example, several prospective studies have observed the progressive deposition of more body fat during childhood and adulthood after a period of catch-up growth during infancy. This leads to differences in body composition relative to infants not exhibiting catch-up growth (Reilly et al. 2005, McCarthy et al. 2007). Catch up growth may totally reestablish the situation to normal or it may be insufficient to do so. If it is incomplete, the individual does not achieve the same adult height that would have been achieved when there was no growth impairment. This depends on the extent to which conditions are optimized during recovery (McCarthy, et al. 2013).



**Fig 2.4. Canalization: Catch up and catch down growth**

*Source:* Verma, D. 2019; <http://epgp.inflibnet.ac.in/Home/ViewSubject?catid=1>

**Check Your Progress 6**

6) What are the different types of variation from normal growth.

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**2.7 GROWTH CURVES AND ETHNIC AND GENDER DIFFERENCES**

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Growth and development is the key indicator of biological maturity. There are two basic determinants of development i.e. heredity and environment. A

complicated mixture of heredity and environment influences, probably acts throughout the whole period of growth. The rate of maturation is sensitive to environmental influences at both the individual and population levels. Population differences i.e ethnic and gender differences in the rate and timing of growth reflect differences in nutrition, environment, socio-economic status and genetics. Secular trends in growth have also been observed among populations undergoing rapid social and economic transitions (Tim, et.al, 2014). Assessment of growth is crucial in child care. India is in a phase of nutrition transition and thus it is vital to update growth references regularly.

Rapid economic and social transition in India has influenced growth patterns of children especially in urban areas. Recent Indian studies suggest that there is a trend towards increase in height, especially in boys and an increase in obesity in both genders (Khadilkar, et.al, 2007; Khadilkar, and Khadilkar, 2004; Ranjani, et.al, 2016). Government of India has accepted the World Health Organization (WHO) 2006 growth standards for monitoring growth of under 5 children since 2010. However, many global as well as Indian studies suggest that these standards remain aspirational and a lot of children get diagnosed as undernourished and stunted when they may be growing appropriately for the given population (Ramchandran, et.al, 2011; Kerac, et.al, 2011).

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## 2.8 SECULAR TREND

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Secular trend is the trend that is observed in a span of several generations. Secular trend in human growth is the progressive pattern of change (over successive generation) in the age at which physical and behavioral milestones are achieved. It has been found that overall economic conditions of world have improved in last 100 years. Children of industrialized countries have acquired a larger body and taller stature more quickly than before; they went to the path of sexual maturity more rapidly than their counterparts in other underprivileged countries. This trend is referred as “The Secular Trend”.

It is revealed by several studies done by different scholars like Roche, (1979); Loesch et.al, (2000); and Arztl, (1990) on the growth pattern of children of some countries, e.g., Germany, England, Poland, Norway, Sweden, North America etc., that the children of these countries show a marked tendency to become progressively larger in size, i.e., becoming taller and heavier, at all ages. This sort of trend is known as secular trend. Nobody knows for certain when this trend started. But the available records indicate that during the last 100 years this phenomenon is happening (Jaiswal, 2013). The secular trend in age at menarche has also been noted. These study shows that among the girls of those countries mentioned above, the age at menarche was gradually decreasing from 1880 to 1980.

What are the reasons behind the secular trend? There is no definite answer. We have already noted that nutrition, state of health, environment, socio-cultural conditions, etc., are associated with growth. Therefore, could better nutrition, improved facilities, desirable environmental conditions, marriage distance in terms of geography as well as mating outside the groups etc., be the reasons? (Jaiswal, 2013).

Check Your Progress 7

7) Define the concept of Secular Trend.

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## 2.9 SUMMARY

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Primates generally have a slow reproductive turnover and drawn-out life histories. Understanding the growth and development of the human organism requires an understanding of nature and nurture, and the complex interplay between the two. The terms growth and development are actually two different terms having separate meanings, but most of the time they are used interchangeably. The stages or phases of growth have been classified in different ways or manners by different scholars. A simple classification of the postnatal period includes four stages like early childhood, later childhood, adolescence and puberty; or, early childhood, middle childhood, late childhood and adolescence. Prenatal development includes all the changes that take place in the womb of the mother. Postnatal growth starts from the time of birth upto adulthood or the time of maturity. Infancy lasts from two weeks to one year of life. Childhood usually ranges from the finish of infancy stages up to the beginning of adolescence. Adolescence is the threshold of adulthood. It extends from twelve years to generally eighteen to twenty years i.e. it starts from the time of puberty and continue up to the onset of adulthood. After the active phase of the life-span, decline process starts resulting in an old age or senescence. Growth is measurable, and therefore, anthropometry plays a very important role in the study of growth. The measurements or the values at successive ages are plotted in a graph to obtain growth curves. Usually two types of growth curves are drawn, namely distance curve and velocity curve. Human growth and development is a complex phenomenon regulated by both, genetic and environmental factors. Growth and development is the key indicator of biological maturity. There are two basic determinants of development i.e. heredity and environment. Secular trend is the trend that is observed in a span of several generations. Secular trend in human growth is the progressive pattern of change (over successive generation) in the age at which physical and behavioral milestones are achieved.

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## 2.11 ANSWERS TO CHECK YOUR PROGRESS

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- 1) The terms growth and development are actually two different terms having separate meanings, but most of the time they are used interchangeably. Terminologically, growth means increase and enlargement of the body or some parts of the body, i.e. the cases where the body becomes heavier, larger, longer etc. On the other hand, development refers to the qualitative changes. These are the changes in kind, structure or organization- a complex process of integrating many structures and functions, which may not be observable or measureable outwardly. Thus, growth can be one of the components of development process or development in its quantitative aspect can be termed as growth. Refer to section 2.1
- 2) The two major periods of growth are prenatal and postnatal.
- 3) The ovum of human at the time of conception is about 0.1 mm in diameter. During the first part or initial segment of this period (ovum), it resembles a homogeneous mass. During the embryonic stage, even though the pace of development is moderate, yet during this time the differentiation process or cycle in the mass to form various regions begins which later on give rise to various parts of the body. The cells are also differentiated into specialized tissues, like nerve, muscle. This process which gives definite shape to different parts is called morphogenesis. By the eighth week the embryo becomes childlike like in appearance. During fetus stage the pace of growth in length as well as weight is considerably high or impressively high. However, in length the peak is reached earlier than in weight. In the former it happens at about 18 weeks. From around 36 weeks the pace of growth of the fetus slows down generally due to the impact of the uterus of the mother.
- 4) Postnatal growth starts from the time of birth upto adulthood or the time of maturity. Post natal period is commonly divided into the following age period:

Neonatal; Infancy or babyhood; Childhood; Adolescence; Adulthood/ Maturity; and Senility or old age. Refer to section 2.4

- 5) Growth is measurable, and therefore, anthropometry plays a very important role in the study of growth. The measurements or the values at successive ages are plotted in a graph to obtain growth curves. Usually two types of growth curves are drawn, namely Distance Curve and Velocity Curve. Refer to section 2.5
- 6) Variations in normal growth represent alternative pathways that enable individual to achieve their growth potential. The general growth curve explains the growth of the body as whole and most of the system of body like skeleton system, respiratory system, digestive system, urinary system and circulatory system that includes heart and blood vessels. Refer to section 2.6
- 7) Secular trend in human growth is the progressive pattern of change (over successive generation) in the age at which physical and behavioral milestones are achieved. Refer to section 2.8



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## UNIT 3 METHODS OF STUDYING GROWTH

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### Contents

- 3.0 Introduction:
- 3.1 Methods of Studying Growth
- 3.2 Cross-sectional Method
  - 3.2.1 Merits and Demerits of Cross-sectional Method
- 3.3 Longitudinal Method
  - 3.3.1 Merits and Demerits of Longitudinal Method
- 3.4 Mixed Longitudinal Method
  - 3.4.1 Merits and Demerits of Mixed Longitudinal Method
- 3.5 Summary
- 3.6 References
- 3.7 Answers to Check Your Progress

### Learning Objectives

After going through this unit you will be able to:

- understand the concepts of different methods of studying human growth;
- differentiate various methods of studying human growth along with their merits and demerits; and
- select the most appropriate method of studying growth in various population groups.

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### 3.0 INTRODUCTION

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We can easily observe differences in body's physical growth every day. Individuals do differ in weight, height, the relative length of the body proportions. The way we move and perform physical activities differs from individual to individuals. All these differences provide us the vision into our growing stage and maturation phase to the overall developmental stage. Physical growth and development are considered as the basic yet the most important characteristics taking place during the lifespan of every living organism. Though the terms "Growth" and "Development" are often used in a replaceable manner but in reality, they are not at all same in the biological sense. Basically, the general shape and design of a growing body is similar for all people. However, there can be some significant variations in the growth rate and the timings or the phases of growth and in the attainment of body size.

Growth refers to the increase in size and weight of the body while on the otherhand development refers to the structural changes taking place within the body during growth. Therefore, growth brings changes in the size of an organism whereas the development brings changes in the form and structure of the body. Growth is defined as the development of a living thing progressively, specifically the process by which the several organs and body parts reach their point where complete physical maturity takes place, starting from the fertilization by cell multiplication

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and intercellular components. It is considered as an essential and vital characteristic of all living beings.

Changes in size are the important factor which are the outcomes of three fundamental cellular processes:

- a rise in the cell number hypertrophy;
- an increase in the cell size i., e, termed as hyperplasia; and
- growth in the intercellular materials or also called as accretion.

Growth occupies a significant and important place while studying individual diversity in form and function in man. For many of these, this also rises through the differential growth rates of specific body parts in relation to others. Watson and Lower (1967) refers to growth as an increase or upsurge in the physical size of the entire or any of the body part/organ. The measurements are taken in centimetres, kilograms, or by using the metabolic balance (retention of calcium and hydrogen in the body). According to Juan Comas, growth is defined as an objective manifestation of hypertrophy and hyperplasia of the organism, and its constituent tissues; which is mainly determined by the post-natal body's size. It is majorly depending on certain factors such as ethnicity, environment, nutrition, etc. Growth has been defined in various forms, like Bogin in 1991 refers to growth as a quantitative increase in body size or mass body; whereby height being measured in centimetres and weight in kilograms; both indicative of the amount of growth that takes place in a child. Measuring the number, weight, or cell size describes the growth of a body or organ at a point in time. The development of the human body begins as soon as a fertilized egg gets embedded within the mother's womb at the time of conception. Development occurs by the production of specialized tissues from unspecialized ones and growth takes place by repeated cell division. At birth, differentiation of cells and tissues gets almost completed, while further development being mainly a matter of growth.

In this unit, we will introduce you to various approaches to studying growth in humans along with their advantages and disadvantages. Growing from a small infant to a fully grown adult is the most fascinating thing one can see in human growth. The process of growth and development in humans is the most incredible and complex phenomenon. The clinical assessment of the individual's growth involves answering numerous questions regarding the amount of growth and the consistent velocity of growth. Is the growth or increase in body size/ mass normal according to age or is it proportionate? Thus, the study of human growth is a very fascinating area of biological anthropology that gives us a clear understanding of all these concepts.

Growth is an assessable and measurable method, and anthropometry plays an important and crucial part while assessing growth. The growth values at consecutive ages are plotted in a graph. The graph is used to attain growth curves. There are usually two types of growth curves that are drawn namely

- distance curve and
- velocity curve.

Here, growth is considered as a function of motion where the object moves from one place to another, covering a distance that can be measurable. At different ages, body parts grow, whereby the increase in the body shape/weight/size can

be measured and depicted on a curve. Such a curve is called a distance curve. Again, all through movement, an object might not be in motion with the same speed. It is then that during the different growth stages, the velocity of growth rate may not be the same; that can be determined from a velocity curve. It may, therefore, kept in mind that different body parts do not grow with the same speed and rate during different stages/ phases of growth.

To have a better and deep comprehension of the changing aspects of human growth, development, and the patterns of average growth, it is important to have a piece of complete knowledge about the several methods that focus on growth. Data can be collected using different approaches or methods of evaluating growth that is then used to establish the growth standards, charts, or norms for a population. Growth standards and charts are used as a dynamic tool for the purpose to teach and encourage health workers and parents to take action for maintaining and improving the growth of a child and screening the growth faltering and directing of proper involvements. Therefore, it becomes important to make you understand the ideas and facts of various methods such as longitudinal, cross-sectional, and mixed longitudinal. All these methods are used for data collection and analysing the growth from the available data along with their advantages and disadvantages. Knowledge produced has its consequences in the scheming of a well-planned growth study.

This information will also help you in choosing an appropriate method to employ while undertaking specific growth studies. In this Unit, an attempt has been made to explain various methods of studying growth in a very simple way and with the help of suitable examples wherever required, to make you understand the importance of each method in studying human growth.

**Check Your Progress 1**

- 1) Name the two types of growth curves.

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### **3.1 METHODS OF STUDYING GROWTH**

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A well-planned growth study is a pre-requisite to obtain information about status of health of a particular population. So, to study the health and nutrition status of a given population it is very much required to use the standardized and well-designed method of growth study. Before starting with the detailed discussion about this topic, a rigorous thought is required to start with collecting data. While collecting data, this should be considered for what purpose you are gathering data. There are some other characteristics as well that should be considered such as regarding method of study, cost, time, efforts involved along with the detailed planning and scheduling of sample procedures or measures, performing training in a careful manner by measuring anthropometric parameters and for the purpose

of analysing data, use of statistical analysis. It is important to select the appropriate and the suitable method that helps in increasing the understanding about the changing aspect of human growth and average patterns of growth. Various approaches are used while conducting the surveys regarding growth of children in different populations. The precise methods for these surveys are used by anthropologists, auxologists, health professionals and nutritionists. At the initial stage of the study, this should be considered that the chosen type of method should depend on the aims and objectives of the study. Let's say if the objective of your study is to determine the growth patterns of a particular community, so at that time, a cross-sectional would suit. So, there are two methods from which growth can be ascertained – (a) cross-sectional study and (b) longitudinal study. During the adolescent growth spurt, variations are examined and investigated using the longitudinal design for several years so that the time the growth spurt was initiated and peak of the growth spurt should be identified. This approach also talks about the magnitude of the spurt quantified. During a cross-sectional study, measurements of participants are taken only one time. It includes the involvements from different ages that helps in providing the general explanation of growth changes which are related to age. Whereas in case of longitudinal method, every single participant is measured for several years. In simple words, same individual or group of subjects/ participants is/ are measured again and again for year to years.

Both of the studies used for assessing the growth have limitations, so to overcome all those drawbacks, there is another approach that is used to study growth is linked longitudinal and mixed-longitudinal methods. This is the third type of study that includes a group of participants followed longitudinally. If during the entire study, any of the subjects leave the study, then other participant of the same age joins the study at some point in time. This is called as mixed longitudinal study. All these studies are described separately in detail.

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## 3.2 CROSS-SECTIONAL METHOD

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Cross-sectional method is one of the most common approach used for studying human growth. This approach involves the measurements of participants having different ages or age groups once during the entire duration of the study. For instance, if during a study, investigator measures all children participated in the study at an age of 9 years are totally different from those at 8 years of age, which in turn are entirely different from the children being measured at 7 years of age and so on. Let's explain this in other words, Cross sectional study is the method that uses different participants at each age. It is a cross-section of a given age group, sex group, or of a given population. Such kind of method does not follow any element of periodic evaluation. Cross-sectional surveys and assessments are ideal for developing distance-curves of growth for any region and type of body. This study is used to determine and analyze the growth and development that provides baseline knowledge at one point in time.

### 3.2.1 Merits and Demerits of Cross-sectional Method

**Merits:** Cross-sectional methods are considered suitable for studying

- ❖ the distributions of several anthropometric measurements among various individuals at different ages;

- ❖ also data gathered using this technique which is regarded as ideal for constructing standards of attained growth, (e.g., height and weight standards);
- ❖ results obtained from the cross-sectional studies performed on growth, maturity, physical activity status or performance of a sample of children and the presence of variability within the sample.

Thus, such studies provide detailed information on the size of the body, maturity stage or performance level, and particularly activity while attaining the survey. Centile distribution of growth patterns could be calculated from cross-sectional study data; which are then often used as the basis for population standards. This method is very useful for creating growth standards for communities, ethnic groups, and populations.

Cross-sectional studies and surveys are significant at identifying and measuring the status of nutrition and health-associated problems dominant in different nutritional status and health-related problems prevailing in different groups at a certain point of time (Malina et al., 2004).

However, after having said this, cross-sectional approaches are also requisite in conditions where continuity of subjects is not possible, such as studying internal organs and other through autopsy.

**Demerits:** Cross-sectional studies

- ❖ do not reveal anything about individual rates of growth (individual increments from one year to the next) adding limitations to the usefulness of even large-scale cross-sectional studies.
- ❖ though estimate the mean rate of growth of a population; however, nothing about the variability around that means is known using this method of study.
- ❖ do not provide detailed and accurate information about timings of specific stages of growth like the inception of “Juvenile Growth Spurt”, the achievement of “Peak Height Velocity” and “Peak Weight Velocity” etc.

This is precisely the most needed to know in a clinical context to compare an individual’s pace of growth with the available standards for the rate of growth in their age. For these longitudinal studies are needed to refer to the relating growth standards. They do not provide any other information about variability around the value of the mean. Thus, be careful as, do not compare the “growth velocity” of any parameter which are based on the cross-sectional study.

**Check Your Progress 2**

2) What are the merits of cross-sectional studies?

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### 3.3 LONGITUDINAL METHOD

In a longitudinal study, at every age, the same participant is used for evaluating the growth patterns. This method deals with the study of human growth over the enrolled participant sometimes, who is measured for body measurements (one or more) at fixed time intervals throughout the study.

In simple words, a longitudinal method includes the recurrent observations on the same individuals at particular intervals over a specific period. This method/approach of studying human growth includes the measurement of each child occasionally involved in the study for 1 or more parameters at set time intervals throughout the study. Let's understand this with an example, if say, children who are measured at 5 years of age will remain the same as those children who were analyzed and examined at 4 years of age. There are two fundamentals of this particular study that are to be studied and considered i.e., the constant sample size and strict observations to a definite periodicity at which participants are required to follow up. This particular study can be performed and carried out for several years. In terms of obtaining the basic type of velocity standards, participants are required to be measured two times i.e., once a year.

There are other forms of Longitudinal study i.e., the short-term longitudinal study also exists extending from 3-6 years of age, for illustration; others from full birth to maturity – longitudinal methods where children might be examined once, twice, quarterly, or sometimes more than that of every year from birth until the age of 20 years and more based on the aims and objective of the ongoing study. Generally, during infancy and early childhood, and adolescence, longitudinal studies are considered to be more useful. So, these two periods of life are characterized by fast change and growth. But the main demerits of a complete longitudinal method are long time consumption to complete the span with a relatively small number of subjects who are followed for the study.

To overcome problems like these 'Linked Longitudinal Studies' are commenced where studies performed covering the ages from 0 to 6, 5 to 11, 10 to 15, 14 and till 20 years. Using this design, the complete age range of the growing phase of human life within a period of six years is spanned and covered. Though, efficient sampling of the population is crucial and important for the smooth collection of data during short time intervals.

Longitudinal studies which are of a long term are important even from birth to maturity for a thorough investigation going on continuously between unfolding events in individuals and sometimes when performing clinical investigations of disorders related to growth. It is important to use appropriate statistical methods while working out the results of different types of studies.

#### 3.3.1 Merits and Demerits of Longitudinal Method

**Merits:** Longitudinal studies

- ❖ provide information about the gross size i.e., attainment of the distance growth along with the individual growth rate that is measured by an increase between two consecutive time intervals for e.g., Kg/year or cm/year.

- ❖ provide us an idea regarding the effectiveness of specific stages such as initiation of juvenile spurt of growth or the spurt of adolescent growth of individuals.
- ❖ help us to learn the genetic and environmental influential parameters on the changing aspects of growth of children; like observing the short-termed illness during childhood; with an understanding that velocity of growth is defined as the innate capacity of a child from their growing age to developmental phase.
- ❖ allow knowing about the span of any disease or stress due to nutrition with which the participant is being distressed for a longer period.
- ❖ intervention plans are noted where participants are included in surveys such as monitoring these studies periodically.

**Demerits:** Longitudinal studies

- ❖ regarded very expensive, requiring great skills to organize as a true longitudinal study from birth to young adulthood would take approximately 18 to 20 years. Such studies are expensive that require a well-organized logistical team making them very laborious and time-consuming.
- ❖ tends to have the number of subjects who complete a longitudinal study small. And that is why it sometimes becomes impossible to maintain reliability and consistency of sample size throughout the complete span of the study, as many participants leave the study because they are migrating to different places due to occupational, social, or financial reasons.

To overcome these situations, these studies require perseverance, patience, and motivation for both subjects and researchers undertaking the study. This is the reason, researchers adhere to the pre-fixed schedule occasionally during the entire term of the study, which then often becomes a little difficult for the participants to adhere to because of certain compelling circumstances.

**Hawthorne Effect**

This effect is a unique concept but not a common phenomenon in relation to human growth. The primary disadvantage of a longitudinal study is mainly the time taken to complete the study, along with the small number of participants that could generally be followed up. In such studies, one of the proper ways to maintain a sample size satisfactorily is by producing a large number of participations among children and their parents involved in the study. Unfortunately, as the involvements increase, it becomes more probable to affect the growth of children who are involved/participated in the study. The process of large involvement of parents in case of longitudinal method generates Hawthorne effect (Blalock, 1970), which achieves that subject should know that they are included or are a part of their study. According to Johnston in 1980, constant and persistent advice should be provided regarding health care, so the parents whose children are involved in the longitudinal study may become aware regarding the relationship that exists between growth and necessity for a proper environment. As a result, they may change the diet of their children, etc. which might lead to an improved and enhanced status of the general growth of the children who are included in the longitudinal study.

Let's see from a methodological perspective, Hawthorne effect is considered to be an innate, estimated, and predictable aspect of the longitudinal approach that helps in understanding human growth. On the bright side, it results in improving the general growth phase and status of children who have participated in this unique longitudinal approach due to its simple nature of the design. While, on the other hand, it seems like a harsh prosecution of the longitudinal method, as infants having the improved status of growth stop by representing the population from which they were drawn initially as a sample. The above concept has not been discussed because it provides information that longitudinal design is not basic to the learning of growth, rather, it majorly focuses that a longitudinal study should only be started after cautious consideration of all parameters of design, of which Hawthorne effect could be a critical one (Bhalla and Kumar, 1986).

### Check Your Progress 3

3) Why has Hawthorne not included as method of studying growth?

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## 3.4 MIXED LONGITUDINAL METHOD

The maximum form of information could be extracted from an amalgamation of techniques of longitudinal and cross-sectional data collection (Tanner, 1951). It is called a mixed-longitudinal study where participants enter and may leave at different ages, giving various degrees of longitudinality to the study. Under some circumstances, the manipulation of increments derived from each participant who is measured twice or more gets reasonably efficient and simple. The mean values of such increments could then be used to calculate more efficient measurement at a given age or 'distance' means at successive ages. For this, the mean value of the measurement at that age at which the greater number of subjects is available (say  $t$ ) and working forwards and backward from it. Thus, the next mean upwards ( $t+1$ ) is obtained by adding the mean increment from  $t$  to  $t+1$  of children present on both occasions. The same is repeated from occasion  $t+1$  to  $t+2$  and so on (Tanner, 1965). Many factors affect the constancy of a sample in longitudinal studies. The most important factor relates to population mobility i.e. a participant's family might need to move out of the area so he/she has to leave the study. Similarly, sometimes subjects may simply get tired of participating (normal attrition). Some children may not report on certain occasions because of ill health, family circumstances, or mortality. Whatever may be the reason for leaving the study it affects the sample size at different age groups. Thus, on one end such a study results in the accumulation of data with missing values, on the other hand, this type of design provides an opportunity to compensate the sample loss by registering new participants at any requisite points of age.

### Check Your Progress 4

4) What is mixed longitudinal study?

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### 3.4.1 Merits and Demerits of Mixed Longitudinal Method

**Merits:** Mixed Longitudinal Study

- ❖ is relatively inexpensive to perform in lesser time, hard work, and exertions compared to pure and basic longitudinal studies.
- ❖ also provide information about both parameters: distance and velocity arches, (i.e., involves both status and rate of growth).

**Demerits:** Demerit of Mixed Longitudinal Study are:

- ❖ for different parameters of the body, estimating the rate of growth velocity from mixed longitudinal method that involves the missing value is a monotonous task, for which different statistical procedures are needed to get the pertinent information in detail out of such data.
- ❖ in some situations, the handling of augmentations derived from each participant is measure two times or more is practically simple and effective. The types of such augmentations might often be used to calculate efficiently measurements at a given age or distance means at successive ages.

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### 3.5 SUMMARY

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While analysing the state of a child’s health and nutrition, assessing the growth and development is considered to be very helpful. And it is the best general index of the nutritional and health status of a specific child, and a population. Normal growth and development in the continuation are signs of indication of good health and nutrition of a child. Failure in growth or abnormal or irregular growth is observed as a basic symptom of the appearance of the disease. And it is almost impossible to assume any study regarding growth without having information about its methodology.

For a successful planning of a growth study, we should be very clear about the data collection methods, size of the sample, tools, and techniques for sampling, also includes relevant anthropometric measurements, training of the research staff, methods for funding, and statistical approach to be employed for analyzing the data. In this unit, an effort has been made to explain different methods of studying human growth along with their merits and demerits. After going through this unit, you can understand various methods of studying human growth, the simple variances between the between cross-sectional, longitudinal, and mixed longitudinal methods and this type of detailed information helps in choosing the most suitable method to be employed for a particular study. The cross-sectional method is the most common method of determining growth. For example, this

collects data on children over a range of ages, each child contributing a measurement at a single moment in time. The distance curve of growth of body dimensions is based on the surveys of a cross-sectional study. These types of studies are used for analyzing growth and development to give information over a period of time. These cross-sectional studies estimate the trends in mean annual growth through differences in the size of consecutively year groups, but they provide no information about the variability of growth. Although cross-sectional studies are seemingly simpler to undertake than longitudinal studies, they require considerable care while sampling so that subjects who got selected for the study features a right cross-section for the population that is being studied.

The longitudinal approach (that is a repeated-measure design) provides the serial data in the form of information that is dependant and then corrected. This type of study includes observations in a repeated manner on the same participant at a particular time interval. As a result, they are laborious, costlier, and time-consuming. Both the subjects and staff must be encouraged and inspired to continue the study for which patience and persistence are must have a parameter for those who participated or are involved in the study.

In mixed longitudinal study, special statistical techniques are needed to get the maximum information out of this data. The period over which assessment of growth takes place is the main existing difference between a longitudinal and a mixed longitudinal study. Longitudinal methods are time taking. If annual velocities are the only concern then two successive surveys one year apart, with say 50% of subjects measured on both occasions, constitutes a mixed longitudinal study that provides all the required growth velocity information, data collection using several research methods which are used to construct the standard or norms of a population for measuring growth.

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### 3.6 REFERENCES

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### **3.7 ANSWERS TO CHECK YOUR PROGRESS**

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- 1) There are usually two types of growth curves drawn namely distance curve and velocity curve.
- 2) Cross-sectional methods bear merit for studying:
  - a) the distributions of several anthropometric measurements among various individuals at
  - b) different ages;
  - c) also, data gathered using this technique is regarded as ideal for constructing standards of attained growth, (e.g., height and weight standards);
  - d) results obtained from the cross-sectional studies performed on growth, maturity, physical activity status or performance of a sample of children and the presence of variability within the sample.
- 3) It provides information that longitudinal design is not basic to the learning of growth, rather, it majorly focuses that a longitudinal study should only be started after cautious consideration of all parameters of design, of which Hawthorne effect could be a critical one
- 4) It is called a mixed-longitudinal study when participants enter and may leave at different ages, giving various degrees of longitudinally to the study.