REVIEW OF LITERATURE
Growth is a natural process which takes place in all living beings. It may be defined as a vital process which brings about changes in the body, like in size, shape and weight, etc. The process of growth is wide and extends from the formation of a fertilised ovum till end of adolescence and so on.

The study of growth in man had a recorded history of only two centuries. The first growth study ever made appeared in the fourth volume of "Natural History" by Buffon in 1749, quoted by Tanner (1979). It was carried out by Montbillard upon his own son. It has been first quoted by Quetelet in 1835 and later by Bowditch in 1877, for the record of seasonal effect on growth rate, which has remarkable agreement with what has been noted by the modern scientists engaged in growth studies (Marshall, 1975). The details of methodology used to measure growth, however, did not find a mention in these studies.

The second pioneer growth study was made on the pupils of the Carlschule in Stuttgart from 1773-1774 by Carleugen again reviewed by Tanner (1979). He...
remarked that this study was a mixed longitudinal with close resemblance to Harpendan growth studies. Carl Eugen had emphasized the concept of velocity of growth and observed that velocity was more important to assess a pupil's health. This study, however, remained unknown till recent times.

Quetelet (1830-31) collected the original series on height and weight and published in 1835. He commented, "I don't think before Buffon any enquiry has been made to determine growth successively from birth to maturity". He further added, "Inhabitants of towns are taller than those of the country". He was the first person to use mathematical expression to express growth data and also attempted to develop law of development of human proportions and suggested fitting of growth curves.

In the early part of the 19th century, a school of growth studies grew up. Roberts insistence on the importance of variation received due attention (Tanner, 1979). Thereafter, importance of growth studies was realized and consistent efforts were directed towards it, at the end of 19th century, most significant growth studies were conducted by the workers like Galton (1874), Bowditch (1877), Boas (1897, 1930, 1932, 1933, 1935), Baldwin (1921), Dawenport (1931, 1932, 1934, 1935), Schultz (1926, 1956 and 1960) and Krogman (1930 and 1955) who contributed a great deal to the understanding
of various growth processes such as adolescent spurt, parent child similarities in body build, secular trends and patterns of growth. This led to the establishment of many more research centres in various parts of the world.

In order to have complete understanding of the growth of a child, knowledge of various developmental periods of life is desirable. The postnatal period of human growth extends from birth to senility, through childhood and adolescence. Each of the subperiod has its own characteristic pattern of growth and development. For instance, during the first two years of life all the body parts grow at a fast rate, from 2-6 years, segments of lower extremity particularly the foot grows at a faster rate than other body parts. In general, the head grows with the least rate and the extremities and their segments at the faster rate during the entire postnatal period of growth. Buffon (1749) in his first edition of "Histories Naturelle" wrote, "There is a quite remarkable thing about growth of human. The fetus grows always more and more upto the moment of birth and in contract the child always grows less and less upto age of puberty, when he grows, one might say, in a bound and arrives in a very little time at the height that he has for always" (quoted from Tanner, 1979).
He made another remark on puberty, "In whole human species, female arrives at puberty earlier than males but the age of puberty differs in different children and seems to depend partly on temperature and climate and on quality of food. Subsequently this fact was amply confirmed by several workers. Garn and Haskell (1960) stated that girls started their pubertal development earlier than boys due to more fat storage in infancy in them as compared to boys.

In the last three decades a large number of anthropometric studies have been done in different parts of India using various combination of measurements and on children of different socio-economic groups. All these studies lacked uniformity in several respects such as methods adopted, use of equipment, expression of age, etc. and thus depicted local standards. ICMR during the years 1956-1965 (ICMR) 1972) undertook the first ever study on all India basis covering all the regions and employing scientific and standard techniques.

In view that the standard for growth for a population should preferably be drawn from children of higher socio-economic strata living in near optimal environments has been supported by several authors (Ghai et al., 1971; Limaye et al., 1974; Aggarwal, 1982; Reddy, 1982; Mehta, 1982; Bhandari, 1982). These workers suggested
that data obtained from well to do groups of the community was in fact norms for that region or community.

The study design was modified by various workers (cross-sectional, semi-longitudinal to longitudinal. In India cross sectional methods have been adopted to study growth and development by Mdani (1963), Aggarwal (1970), Khurana (1971), Hath et al. (1978). Banik Datta et al. (1962) emphasized though the longitudinal method is the only one which can give complete description of growth phenomenon but longitudinal studies were costly, long term and laborious.

Factors Affecting Growth

There are many exogenous and endogenous factors which affect the growth and development of a person. All the factors are not taken in account while doing a study. So we will study these factors separately.

1. Endogenous factors:

Effect of the genetic constitution upon a child's growth is supreme over any other factor. Hewitt (1957 and 1958) reported that siblings resembled in growth rate, skeletal maturity and tissue composition. Livson et al. (1962) found a positive and significant correlation in height from birth to maturity between father and child and mother and child for each age.
Kano and Chung (1975), Greulich (1976) and Johnston et al. (1976 and 1978) compared ethnic groups sharing similar genetic endowment living in different environment and different ethnic groups living in the same environment. They found differences in height between similar ethnic groups at prepubertal age and not between the two groups having different ethnic background. Thoma (1960) and Tanner (1962) commented on difficulty to dissociate the racial factors from the effect of nutrition and socio-economic status. Jenss (1940) studied the differences in the rate of growth in different racial groups of same socio-economic status.

Robinson et al. (1971) observed racial differences in skinfolds of triceps and subscapular amongst the English and the Negroes. Johnston et al. (1974) observed consistent findings between whites and Negroes and suggested that differences in triceps was due to hereditary factors and in subscapular skinfold was due to environment factors. Britishers and French Canadians had better triceps and subscapular fat than of Americans and also had better height and weight (Jenicek and Derirjian, 1977).

Ito (1942) reported different mean ages at menarche for Mexican, Japanese, European, Negroes and Chinese and attributed it to racial and genetic origin.
He also observed that Japanese girls born and reared in California menstruated 1½ years earlier than those born in California and reared in Japan. These findings were later supported by Greulich (1957). An international review provided by Bhalla (1975) indicated the difference of more than two years in the age at menarche amongst Indian population and differences of 2-3 years in the mean age of menarche amongst western and European population.

Environmental factors:

A child’s genetic make up gives him the potential to develop specific characteristics in a predetermined sequence. Buzina (1976) observed significant improvement in physical characters following improvement in environment. Marshall (1981) stated that a genetically dissimilar population might respond differently in the same environment and vice versa.

(a) Nutrition:

The fulfilment of growth potentials is initially linked with optimal nutrition as observed by Frisch and Revelle (1969) who studied growth through body weight, cross-sectionally in seven Latin American and Asian countries each. They observed a direct relationship
between calories supplied and growth as estimated by body weight. The inadequate nutrition was found to delay adolescent spurt. A significant difference in physique was found depending upon caloric intake (Pevkos, 1953; Bhattacharya et al., 1981). Garn et al. (1974) suggested a direct effect of the level of fat and height and a cumulative fat related difference in annual rate of growth as observed in European girls. It was found that calcium intake (Takahashi, 1966) and protein intake (Malcolm, 1979) were directly responsible for variation in height. Tanner (1976) and Malcolm (1979) commented that poor diet slowed down the growth in a child. Reduction in peak height velocity may be a better indicator of undernutrition than peak weight velocity. The extent of growth retardation depends upon the degree of malnutrition (Gopalan, 1957; Rao et al. 1959; Patwardhan, 1961; Srikantia, 1969). Gopalan and Narsingha Rao (1971) concluded that poor growth of Indians was largely due to poor nutrition.

It is thus evident that nutrition had direct effect on physique but this is, however, not proven with regards to the influence of diet on the appearance of secondary sex characters. Wilson and Sutherland (1950), Israel (1967), Ghosh et al. (1973), Tanner (1973),
Bhalla and Srivastava (1974), Malcolm et al. (1979) had shown that onset of puberty is even delayed due to poor diet; whereas Roberts and Dann (1967) and Roberts et al. (1977) observed no effect of diet on puberty. Nutrition may be a determining factor in fulfilling genetic potentials as strongly suggested by the change of body size of the Japanese with improvement in calories and proteins (Frisch and Revelle, 1969). Easwaran and Devadass (1981) remarked that body is a product of nutrition and is the most vital factor affecting growth of children while, Nelson (1980) and Kerr et al. (1982) found that before accepting nutrition as a major factor to have bigger children, variability due to other factors should be taken into account because the diet available would depend upon parent's income, education and their surroundings (Currinbhay, 1963; Udani, 1963; Ghai and Sandhu, 1968; Banik Datta, 1970; Raghvan et al., 1974).

Socio-Economic Status

Parent's social class is commonly used to assess the association between socio-economic status of the family and child's growth. The fact that children from different socio-economic levels differ in overall body size at all ages which had been investigated thoroughly by various workers. The
upper class being always more advanced along the
course of maturity (Meredith, 1941-1951; Michelson,
1944; Friend and Bransby, 1947; Greenberg and Bryan,
1951; Hammond, 1953; Tanner, 1962 and 1976; Udani,
1963; Aggarwal et al., 1974; Tripathi et al., 1976;
Datta Banik et al., 1982; Kaul et al., 1982; Mohindra.
1987).

Most studies had defined socio-economic status
according to the occupation of the father but some
had simply compared children in a school known to
draw its pupils from the higher income group with
the one whose pupils were drawn from low socio-economic
status.

But no single factor can by itself depict
the picture regarding socio-economic status of individual.
Kuppuswamy (1962) devised a technique in which numerical
scores are assigned according to education, income
and occupation of the individual. The socio-economic
status is arrived at by adding up the total scores.

Kuppuswamy classification was further improved
upon by ICMR 1972 which included the factor of urban
rural residence and divided the community into six
socio-economic classes. Seal et al. (1962) divided
the population into five socio-economic groups based
on the annual consumption per capita in rupees.
According to Parsad (1970) family income is the most important factor for the socio-economic classification. However, keeping into view the peculiar conditions prevalent in India where family size varies to a great extent, use of per capita income per month has been suggested as the basis for describing the socio-economic status of the families.

It was also observed that children belonging to upper socio-economic group attained sexual maturity earlier than in those belonging to lower socio-economic group (Wifinden and Smallwood, 1958; Michelson, 1944; Kark, 1956; Shakir, 1971; Robert et al., 1977; Kaul et al. 1983).

Oduntan et al. (1976) suggested that parent's education and occupation levels were responsible for attainment of puberty. Children of educated parents attained puberty earlier. Rona and Chinn (1982) found skinfold thicknesses were inversely related to the social class. The major part of these social class differences were due to earlier maturation in well to do classes while children of poor section took about a year or two more to mature (Tanner and Marshall, 1968; Marshall, 1975; Tripathi, 1976; Eveleth and Tanner, 1976).
Family Size:

Growth differences are also found to be closely related to home conditions than to strictly economic class of the families (Bransby et al., 1946). Tanner et al. (1962) stated that it was obvious that more mouths to feed and children to bother about, less well fed and perhaps the general care of a child was done. Several observers had been able to find relationships between the number of children in poor socio-economic class families and their heights and weights (Douglas Blomfield, 1958; Scott, 1961; Tanner, 1962; Millar et al., 1974; Fox et al., 1981).

Scott et al. (1961) and Roberts and Dann (1967) observed that children from larger families were older in attaining sexual maturity. On the other hand Singh and Sodhi (1979) and Richter (1980) found no association between growth and family size.

Urban and Rural:

Several investigators have examined the influence of an urban and rural background on the growth of children. The information gathered is rather conflicting. Investigators like Wolanski and Lasota (1964), Meredith (1971) and Sathyavathi et al. (1981) have shown that urban children were taller and heavier than
their rural peers. However, a little difference in height and weight existed between urban slum and rural children (Marley et al. 1968; ICMR, 1972; Richardson, 1973; James, 1974). Comparatively small size of rural children might be due to lack of awareness of sanitation and good food and being illiterate. More infection is prevailing due to poor sanitation and hence responsible for spreading diseases and illness which in turn effect the child's growth to a large extent. On the other hand, Vanwieringen et al. (1971) from Netherlands; Hammil et al. (1972) from USA and Jones et al. (1973) from Australia noted no differences amongst urban and rural children.

Illness:

Most illnesses had an adverse effect on growth and its degree depended upon the nature and duration of illness. The minor illness might or might not effect growth depending upon environment in which a child was reared while a major illness invariably had an everlasting effect. The extent of retardation of growth had direct relationship to the severity of illness.

The nature of illness is also important. Chronic renal failure and diabetes mellitus affected
not only the rate of growth and maturity but also the size and shape of body proportion (Bauer, 1954; Vardhan et al., 1961; Lacey and Parkin, 1974). Hewitt et al. (1955) and Acheson (1960) found that asthma and other respiratory illnesses affected height significantly. Swaminathan et al. (1964) observed a sharp decline in weight of Indian children due to frequent and prolonged illnesses especially gastroenteritis with inadequate treatment and PEM. Similar results were found by Sood Ajay et al. (1984).

Seasonal and Climatic:

Buffon (1749) had suspected that summer and winter growth in height in children might not proceed at an equal rate. Gain in height was found to be faster in autumn (Nylin, 1929; Reynolds and Sontag, 1944; Bojlen et al., 1971; Marshall, 1975). This is true at all ages including adolescence. Tanner (1962) and Marshall (1971) reported that most children reached their maximal growth in height during periods between March and July and slowest in the periods between September and February. Whitacre and Grimes (1959) suggested faster growth of children living in southern Texas relative to children living in Northern Texas. This might be due to warmer climate conditions.
of Southern Texas. Wilson and Sutherland (1950) and Marshall (1975) found no difference in the onset of menarche in girls of hot humid area of central India and those in hot dry area of Northern Nigeria.

Secular Trends:

During the past 100 years information had been gathered which indicated a secular trend towards taller stature and early maturation (Barwin, 1964; Eveleth and Tanner, 1976; Brundtland et al. 1980; Low, 1982). This trend was noticeable irrespective of population differences or state of development of the country. It appeared to have reached a plateau in the developed countries. For example no further enhancement in growth is evident in UK after 1956 (Tanner, 1979; Marshall, 1981). Another equally important aspect is the study design, sample selection and its homogeneity or heterogeneity and also the statistical methods used for analysing the data. Seth et al. (1972) pointed out that Indian boys attained lower maximal growth than European. This might be due to an artefact resulting from analytical methods used.
Indicators of Nutritional Status

1. Head circumference and chest circumference:

These have been studied by many workers (Jelliffe, 1966; Neuman et al., 1969; Tanner, 1973) as indicators of nutritional status. Udani (1963) observed that head circumference remained bigger than the chest for as much as 3-4 years in lower socio-economic status. Banik Datta et al. (1970) reported that the circumferences of head and chest in males were higher than those in females at all ages. Bhandari et al. (1975) also showed that head and chest circumferences were comparable with national standards. As the rate of growth is different for different parts of body at different periods of growth, the study of change in head circumference makes it important part of growth study. Hass (1952) studied 98 cases and reported mean figures of skull breadth at various age groups. Meredith (1953) studied growth in head width during first 12 years of life. Walia et al. (1972) studied various head dimensions in 200 children of 0-4 years and reported that girls showed higher measurements than boys up to 6 months of age after which girls showed lower measurements than boys till age of 5 years.
Bhandari et al. (1975) studied nutritional and health status in rural boys and found that head circumference of children studied were larger at 5, 6, 8, 10, 13, 14 years than ICMR group. Rath et al. (1978) showed that head circumference gradually increased with age by 4.19 cm for boys and 3.99 for girls between 5-15 years. It was further correlated with the adolescent growth spurt, which was at the age of 10 years for boys and 9 years for girls. Olensted et al. (1985) updated the head circumference charts. Alen P.Roche et al. (1987) made new references of head circumference from birth to 18 years. This study differed only slightly from NCHS standards from birth to 36 months.

2. Skinfold thickness:

Standards for height and weight do not indicate as to how fat or thin a child is in relation to other children. Tanner and Whitehouse (1966) prepared standards for subcutaneous fat in British children by using Harpenden skinfold calipers at arm (triceps) and on the body (sub-scapular). Considerable differences in growth curves between limb and body fat were seen and they recommended that these two measurements should be taken together. The first study of skinfold thickness
was done by Baker and Hunt (1958) and showed the growth and inter-relation of skinfold in man. Following this a number of studies were done by Hammond (1955), Fletcher (1962), Suzuki (1964), Fry et al. (1965), Malinia (1966) and Robinson (1971). Jelliffe and Jelliffe (1960) devised a formula to calculate muscle mass of mid-upper arm with the help of mid-arm circumference and skinfold thickness at triceps. Farr (1966) and Farmer (1985) have done studies on skinfold thickness in neonates and children. Singh and Sidhu (1979) studied skinfold thickness at triceps and subscapular region in preadolescent Punjabi girls. They observed that triceps skinfold thickness decreased from 6-9 years of age and registered an increase for small period and again decrease was noted, whereas subscapular skinfold thickness and showed continuous increase during the period under study. Rona and Chinn (1982) found skinfold thickness were inversely related to social class. Robinson et al. (1971) observed racial differences in skinfolds of triceps and subscapular amongst the English and Negroes. Johnston et al. (1974) observed consistent findings between Whites and Negroes and suggested that differences in triceps was due to hereditary factors and in subscapular skinfold thickness due to environment. Britishers and French
Canadians had better triceps and subscapular fat than of Americans and also had better height and weight (Jenicek and Demirfion, 1977). Sood and Kapil Umesh (1984) studied skinfold pattern in rural school boys and found Indian boys to have significantly lower mean values for triceps, and suprailiac skinfold thickness while the subscapular skinfold was comparable with the similar skinfold for British boys.

3. Mid-arm circumference :

Jelliffe and Jelliffe (1969) suggested that the status of child nutrition in a community could be assessed by measurement of mid arm circumference. Later this measurement was made use to measure the nutritional status by Shakir (1975), Somar and Lowenstein (1975), Martorell et al. (1976), Farquharson (1976). Burgert et al. (1979) and Ian McDowell (1982) studied arm circumference was shown to be more accurate. Raghavan et al. (1974) after extensive studies have prepared Indian standards. Rath and Shanti Gosh et al. (1978) found values of mid-arm circumference of upper socio-economic status children between 50th and 25th American percentiles.
Segmental Changes

Many workers like Talbot (1924), Ruckdor (1925), Davenport (1932) and Meredith (1943) have recorded serial measurements in foot length in babies at varying period of postnatal life. Various investigators had shown correlation between different parts of body (hand, foot measurements and weight of individual). MacDonnel stature from hand breadth, face breadth, middle finger length and foot length and derived different regression formulae. Suneel et al. (1979) have shown a significant correlation between height, foot length and foot breadth. Suroff and Vare (1979) had derived the stature from the length of superior extermity and its segments. Sexena et al. (1981) calculated stature of Indian Medical students from head length only and found significant correlation between head length and stature and derived regression equations to estimate strature from head length. Sexena (1984) studied 100 adult Nigerian medical students between age 20-30 years and found significant correlation between the strature of individual and hand length, hand breadth and sole length.

Development of Secondary Sex Characters

There is a natural sequence in the development of the sex characters. This sequence is followed
with great consistency in an individual, however, there are variations in the chronological ages at which different milestones are attained among members of same sex. There is also wide variability in size and general appearance of sex characters in persons of same chronological age between 9-18 years. The usual pattern of development of female secondary sex characters is that breast development is first event followed by appearance of pubic hair. Axillary hair appear a little later. Menarche generally follows the appearance of these secondary sex character. Occasionally it may occur before axillary hair develop (ICMR, 1972). In males the genital growth occurred earlier followed by appearance of pubic hair. The axillary hair and voice change occurred afterwards (ICMR, 1972).

Reynolds (1946), Marshall and Tanner (1964), Indirabai and Vijayalakshmi (1973), Zacharias et al. (1976), Bhargava et al. (1980) and Kaul et al. (1983) observed that the average age for the appearance of breast and pubic hair was found to be around 10/11 years and the mean age of appearance of axillary hair was observed to be at nearly 12 years. Marshall and Tanner (1969) also pointed out that the adolescent growth spurt and development of secondary sex characters occurred almost simultaneously and took approximately
3 years to complete. Menarche usually occurred in the later half of this period coinciding with III and IV stage of breast and pubic hair development (Tanner, 1962; Marshall and Tanner, 1969; Indirabai and Vijayalakshmi, 1973). A considerable variation in the onset of menarche had been reported in the literature. A review on the age of menarche of Indian girls provided by Bhalla (1975) indicated that mean age of menarche of Indian girls ranged between 12-14 years and that of European and American girls varied between 12-15 years of age. Marshall ( ) also stated that no European or American mean for menarcheal age were greater than 14 years and beyond 15 years for Indians while of Africans extended to over 17 years and those of New Guineas ranged from 15 to a little over 18 years. This wide difference might be primarily attributed to the genetic variation. The peak of adolescent growth spurt in height is reached in the average girl at stage B₃ and PH₃ and in the average boy at the stage G₄ and PH₄ (Reynolds and Wines, 1948; Nicolson and Hanley, 1953; Van Wierigen et al. 1968; Marshall and Tanner, 1969 and 1970).

*B₃  -  Breast development Stage 3
PH₃  -  Pubic hair development Stage 3
G₄   -  Genital growth Stage 4
PH₄  -  Pubic hair development Stage 4
The genital and pubic hair growth in males started at mean age of 11.64/13.44 respectively and took almost 3 years for complete maturation (Tanner and Marshall, 1970). According to All India (pooled) figures the genital and pubic hair growth started at 14.00 and 13.82 (ICMR, 1972).

It had been proved that children belonging to low socio-economic status took 1.2 years more to mature (Tanner and Marshall, 1968, 1975; Tripathi, 1976; Eveleth and Tanner, 1976).

**Relationship Between Physical Growth and Sexual Maturity**

There is a close association between appearance of secondary sex characters and the peak height velocity (Mullen, 1940; Deming, 1957; Tanner, 1962; Vardhan, 1962; Agarwal, 1974b; Onat and Ertem, 1974; Faust, 1977; Brundtland et al., 1981). Frisch and Revelle (1970) observed that menarche occurred only after the attainment of a minimum body weight i.e. 47 kg and in 1974 they revised their opinion and held the view that overall body build had a correlation to menarche. Similar findings were observed by Von't Hof and Reode (1977) and Cameron (1976). Richardson and Rieters (1977) reported that South African girls with early menarche had greater weight for height.
Garn and Haskell (1960) had shown that the early maturers had more subcutaneous fat at all ages from 7½ to puberty in both sexes. They interpreted that the degree of fat reflected calories and that higher the caloric intake, faster the maturation was. Bodzsar (1980) found that menarche triggered significantly earlier in endomorphic girls than ectomorphic ones.

The best relationship was found between skeletal maturity and age at which the secondary sex characters appeared (Shuttleworth, 1938; Stuart, 1946). The children who were advanced in skeletal maturation at the time of adolescence, also matured earlier. Stuart (1946) pointed out that menarche in girls is the most definite single event indicating sexual maturity. Hence, all aspects of growth should be related to menarche. The girls who developed their secondary sex characters early would have their adolescent growth spurt early (Stone and Barker, 1937; Nicholson and Hanley, 1953; Onat and Ertem, 1974; Agarwal et al., 1974b; Faust, 1977). This would bear a relation to linear skeletal growth. Hence a child who attained height higher than standards for a given age would be faster than others in his journey to maturity.

Davenport (1926 and 1931) demonstrated that adolescent spurt and growth was a characteristic
phenomenon and focussed attention on the marked differences between the children of the same age, on the age at which adolescent acceleration in growth began and ended and in the magnitude of the spurt. Shuttleworth (1940) observed that children passed through the adolescent phase of accelerated growth at widely different chronological ages but they followed much the same sequences for any particular measurement regardless of initiation of adolescent growth. Dimock (1935) concluded that the difference in height and weight of children of the same chronological age could have different pubescent status and it could be as great as 2 years. Similar findings have been observed by other workers (Reynolds and Wines, 1948; Tanner, 1962).

There were differences in physique between those who mature early and those who mature late. It was found that the time and character of the spurt themselves seemed to be related. The earlier the spurt occurred, more intense it appeared to be. It seemed, therefore, that in early matures, the whole process went off more quickly and intensly. This fact was discovered by Boas (1930 and 1932) and thoroughly
investigated by Shuttleworth (1937 and 1938). This effect was not confined to height alone but observed in skeletal dimension and even in such a highly growing one as head width (Goldstein, 1939; Shuttleworth, 1938).