3-1985

Developmental Ossification Patterns in the Human Sternum from Fetus to 19 Years of Age: A Cross Sectional Study Based on Radiographic Analysis

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To the Graduate Council:

I am submitting herewith a dissertation written by William Cesar Rodriguez III entitled "Developmental Ossification Patterns in the Human Sternum from Fetus to 19 Years of Age: A Cross Sectional Study Based on Radiographic Analysis." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Anthropology.

William M. Bass, Major Professor

We have read this dissertation and recommend its acceptance:

Richard Jantz, Randy Pedigo, Ann Bass

Accepted for the Council:

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Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

To The Graduate Council:

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Accepted for the Council:

Vice Chancellor
Graduate Studies and Research

DEVELOPMENTAL OSSIFICATION PATTERNS IN THE HUMAN STERNUM FROM FETUS TO 19 YEARS OF AGE: A CROSS SECTIONAL STUDY BASED ON RADIOGRAPHIC ANALYSIS

A Dissertation
Presented for the
Doctor of Philosophy
Degree
The University of Tennessee, Knoxville

William Cesar Rodriguez III

March 1985

DEDICATION

I dedicate this dissertation to my wife Karleen and our first born child Christina Victoria Moreau. This dissertation along with other research took much of my time away from my wife and daughter. I regret missing the time loss but hope that my reaching this academic goal of Ph.D. will allow me to make up for that time.

ACKNOWLEDGEMENTS

I am most indebted to my committee chairman, Dr. William M. Bass who through the years has shared his valuable knowledge and experience with me. I feel honored to have trained under him as I consider him the best in his field. With the passage of time I hope to someday be as good as he is, which in all respects is a most admiral goal. Sincere appreciation is also extended to other dissertation committee members: Dr. Richard L. Jantz, who was always willing to listen and explain; Dr. Ann Bass, who was always kind and understanding; and Dr. Randy Pedigo, who is not only an excellent medical examiner but a true friend.

A special thanks is given to Dr. William F. McCormick who provided all materials for this research. Dr. McCormick opened my eyes to many new concepts and I have nothing but the greatest admiration for his expertise in medicine and anthropology. I value his friendship and hope that it will continue to grow through the years.

I would also like to thank my fellow students whose friendship and assistance have made my stay at the university a cherishable one.

I am indebted to all of my extended family for their moral support and strong interest in my graduate studies.

Lastly a special thanks to my parents for their love and understanding throughout the years which have helped me attain this goal.

ABSTRACT

The developmental ossification patterns in the sternal radiographs of 479 autopsy cases were analyzed in an attempt to determine the variation of ossification patterns in relation to age, sex and race. This study population consisted of 302 fetuses or newborns ranging in gestational age from 18 to 38 weeks, and 177 children or subadults ranging in age from 1 month to 19 years of age. Examination of the sternal radiographs revealed that the number and patterning of ossification centers in the sternum varied with age.

Variation in ossification patterning was found to be greatest during pre-natal and early post-natal development. Also with the increase of age, the mean number of ossification centers in the sternum increased. This increase in the number of ossification centers continued up to approximately 140 weeks after birth, after which there was a leveling due to fusion of adjacent centers. Also observed in this study were various sternal anamolies, primarily pre-mature ossification and fusion.

Statistical analysis of age, sex and race differences in the number of ossification centers in the sternum revealed variation as to age and sex. It was found that during early sternal development (18 weeks gestation to 140 weeks post birth) the mean number of ossification centers was greater in males than in females. Racial variation in the number of ossification centers, was found not to be statistically significant.

Application of this data can be used to up-date present anatomical literature concerning the development of the sternum. The findings pertaining to the sex differences in the developing sternum may provide an insight to sexual dimorphism in the adult sternum in future research.

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CHAPTER I

INTRODUCTION

The human sternum is probably one of the least studied skeletal elements in the human body. Anthropologists and anatomists in the past, for the most part, have studied the sternum only in the context of sexual dimorphism and pertaining only to the final or "adult" sternal form. Only a few studies have been devoted to the developmental ossification of the sternum which in turn, has led to inaccurate or vague descriptions of the processes which lead to the adult form.

Recent research on the adult human sternum and associated costal cartilages has shown great potential for use in forensic anthropology. These studies found that the degree of sternal costal cartilage calcification can be used as an accurate method of age determination. The pattern of costal cartilage calcification has also been shown to be an accurate indicator of sex. It is is hoped that the findings of this dissertation research might also provide such useful information.

The Adult Sternum and its Embryological Origin

The sternum has been described morphologically by many anatomists, however the most familiar or most often used description is that given by Henry Gray in his classic anatomical textbook Gray's Anatomy (Pick and Howden 1977:124-125). The sternum as quoted in the revised American edition of "Gray's Anatomy" . . .

is a flat, narrow bone, situated in the median line of the

front of the chest, and consisting, in the adult, of three portions. It has been likened to an ancient sword; the upper piece, representing the handle, is termed the Manubrium; the middle and larger piece, which represents the chief part of the blade, is termed the meso-sternum or gladiolus; and the inferior piece, which is likened to the point of the sword, is termed the xiphoid appendix or enisiform.

In its natural position its inclination is oblique from above downward and forward. It is slightly convex in front, concave behind, broad above, becoming narrowed at the point where the first and second pieces are connected, after which it again widens a little, and is pointed at its extremity. Its average length in the adult is about seven inches, being rather longer in the male than in the female.

The first piece of the sternum, or Manubrium, is of a somewhat triangular form, broad and thick above, narrow below at its junction with the middle piece. Its anterior surface, convex from side to side, concave from above downward, is smooth, and affords attachment on each side to the Pectoralis major and sternal origin of the Sterno-cleido-mastoid muscle. Its posterior surface, concave and smooth, afford attachment on each side to the Sterno-hyoid and Sterno-thyroid muscles. The superior border, the thickest, presents at its center the pre-sternal notch; and on each side an oval articular surface, directed upward, backward, and outward, for articulation with the sternal end of the clavical. The inferior border presents an oval, rough surface, covered in the recent state with a thin layer of cartilage, for articulation with the second portion of the bone. The lateral borders are marked above by a depression for the first costal cartilage, and below by a small facet, which with a similar facet on the upper angle of the middle portion of the bone, forms a notch for the reception of the costal cartilage of the second rib. These articular surfaces are separated by a narrow, curved edge, which slopes from above downward and inward.

The second piece of the sternum, or Meso-sternum, considerably longer, narrower, and thinner than the first piece, is broader below than above. Its anterior surface is nearly flat, directed upward and forward, and marked by three transverse lines which cross the bone opposite the third, fourth, and fifth articular depressions. These lines are produced by the union of the four separate pieces of which this part of the bone consists at an early period of life.

At the junction of the third and fourth pieces is occasionally seen an orifice, the sternal foramina; it varies in size and form in different individuals, and pierces the bone from before backward. This surface affords

attachment on each side to the sternal origin of the Pectoralis major. The posterior surface, slightly concave, is also marked by three transverse lines, but they are less distinct than those in front: this surface affords attachment below, on each side, to the Triangularis sterni muscle, and occasionally presents the posterior opening of the sternal foramina.

The superior border of the manubrium presents an oval surface for articulation with the ensiform appendix. Each lateral border presents, at each superior angle, a small facet, which with a similar facet on the manubrium, forms a cavity for the cartilage of the second rib; the four succeeding angular depressions receive the cartilages of the third, fourth, fifth, and sixth ribs; with each inferior angle presenting a small facet, which, with a corresponding one on the ensiform appendix, forms a notch for the cartilage of the seventh rib. These articular depressions are separated by a series of curved interarticular intervals, which diminish in length from above downward, and correspond to the intercostal spaces.

Most of the cartilages belonging to the true ribs, as will be seen from the foregoing description, articulate with the sternum at the line of junction of two of its primitive component segments. This is well seen in many of the lower animals, where the separate parts of the bone remain united longer than in man.

The third piece of the sternum, Xiphoid appendix or Ensiform, is the smallest of the three; it is thin and elongated in form, cartilagenous in structure in youth, but more or less ossified at its upper part in the adult. Its anterior surface affords attachment to the chondro-Xiphoid ligament; its posterior surface, to some of the fibers of the Diaphragm and Triangularis sterni muscles; its lateral borders, to the aponeurosis of the abdominal muscles. Above it articulars with the lower end of the gladiolus, and at each superior angle presents a facet for the lower half of the cartilage of the seventh rib; below, by its pointed extremity it gives attachment to the linea alba. This portion of the sternum is various in appearance, being sometimes pointed broad, and thin, sometimes bifid or perforated by a round hole, occasionally curved or deflected considerably to one or the other side.

Structurally the sternum "is composed of delicate cancellous structure, covered by a thin layer of compact tissue, which is thickest in the manubrium between the articular facets for the clavicals" (Pick and Howden 1977:125). The earliest appearance of the

sternum in humans, occurs as a pair of mesenchymal bands that can be observed in human embryos of six weeks (Arey 1960:410). The mesenchynal bonds lie ventrolaterally in the chest wall and at first have no bond either with the ribs or with each other. After attachment of the ribs the mesenchymal bars fuse progressively in a cephalocaudal direction and at the same time consolidating a smaller mesial mass which is similar to the presternum of lower animals, and two variable suprasternal elements (Arey 1960:410).

At approximately nine weeks the fusion of the cartilaginous bars is complete. The cranial end of the early sternum possesses two imperfectly separated suprasternal cartilages with which the clavicals articulate. These suprasternal cartilages usually fuse with the manubrium of the sternum and lose their identity (Arey, 1960, p. 411). Ossification begins about 21 weeks, but all the centers are not present until childhood. Ossification centers have been shown to be highly variable, although a bilateral tendency is evident (McCormick and Nichols 1981). The segmentation of the sternum into sternebrae is acquired secondarily. Figure 1, Appendix, illustrates the early development of the human sternum, as previously described.

Previous Studies on Developmental Ossification Patterns (1954 to Present)

First to be discussed, dealing with the developmental ossification patterns in the sternum, is a paper by T. D. Stewart. Stewart (1954) discussed little in the way of early developmental ossification but examined the metamorphosis of the joints of the

sternum in relation to later age changes. The changes expounded on by Stewart consisted of the changes between the areas of sternal articulation from the ages of 17 to 35 years of age. Although a significant work, this manuscript shed little light on this study with exception of reference to fusion of the mesosternum segments. One of the most detailed studies on developmental ossification patterns of the human sternum was published by Ashley in 1956. His manuscript entitled "The Relationship between the Pattern of Ossification and the Definitive Shape of the Mesosternum in Man," is an excellent work and serve as a basis for this study. The main focus of Ashley's study was to determine the relationship between the early developing sternum to that of the final adult form.

In the introduction of his paper Ashley provides a review of the early anatomical literature concerned with the development of the sternum. He points out that in many of the early manuscripts, the authors hinted at the possible relationship between the manner of ossification and the definitive shape of mesosternum, although the precise nature of this relationship had never been researched. Ashley stated that early observations of the developing sternum revealed the great inconsistencies, "not only in the times of appearance of the various ossification centres, but also in the size attained by each centre" (Ashley 1956:102).

Earlier research by Ashley in 1951 and 1953 presented the first evidence showing a direct relationship between the adult mesosternum and the arrangement and number of the ossification centers from which

the bone develops (Ashley 1951, 1953). These earlier studies by Ashley were based on observation of the mesosternum at various ages from anatomical collections. Ashley also provides discussion on the occurrence of sternal foramen, and the various speculations of earlier researchers, of their origin and function.

The population examined by Ashley as noted in his 1956 publication consisted of over a thousand individuals with the great majority of specimens belonging to the Paterson anatomical collection at Liverpool University, England. Approximately 794 adult (118 African and 676 European) mesosternums were examined by visual and radiographic methods. Subadults as well as fetal and embryo specimens were also examined. The study group noted as subadults, consisted of approximately 140 individuals (seven Africans and 133 Europeans) between the ages of two and 19 years of age. Another group noted as infants included 73 Europeans between birth and one year of age. The earliest developmental sample examined by Ashley consisted of 393 European fetus, ranging in gestational age from 10 weeks to term, and 10 embryos ranging in size from four to 40 mm (four to nine weeks).

Ashley's analysis of the adult mesosternum specimens involved visual inspection of general shape and of foramina, notches, grooves, ridges and abnormalities if present. Measurements were also taken on the adult specimens in order to provide two indices, manubrium-corpis index and the mesosternal relative width index. Analysis of the subadult fetal and embryo mesosternums involved radiography and histological sectioning.

From the analysis of the subadult mesosternums, Ashley described 16 "regular" possible patterns of developmental ossification which could be further grouped into four "basic patterns," from these four patterns, three final adult sternal forms could be correlated. The description of Ashley's four "basic patterns" (Ashley 1956:90-91), are as follows:

> Ossification pattern type I: In each of the first three segments of the mesosternum the ossification centres are usually single and always mid-line. Occasionally they may be double vertically, but still, strictly mid-line in position. In the fourth segment centre(s) may be single double or completely absent.
>
> Ossification pattern type II: In either the first or first and second segment(s) of the mesosternum the ossification centre(s) is/are single and mid-line, whereas in the second (in some), third (in all) and fourth (in some) the centres are double, and bilaterally or obliquely placed.
>
> Ossification pattern type III: In each of the first three segments of the mesosternum the ossification centers are double (bilaterally or obliquely), and in the fourth segment the centre(s) may be double, single or absent.
>
> Ossification pattern type IV: In either the first or first and second segment(s) the centres are double, bilaterally or obliquely; whereas in the third they are single and in the fourth single or absent" (Ashley 1956).

Ashley's classification of ossification patterns in 357 fetal sterna ranging from five months to nine months gestational age placed 26% of the sterna as Type I, 31% as Type II, 12% as Type III and 31% as indeterminate. In his classification of 224 post-natal sterna ranging in age from birth to 19 years of age, Ashley placed 25% of the sterna as Type I, 52% as Type II, 8% as Type III and 15% as indeterminate. It is important to note that Ashley reported that the

manubrium "in all of his "types" was shown to ossify from a single center.

A more recent manuscript reporting on the developmental ossification in the human sternum, was published by McCormick and Nichols in 1981. The authors' paper entitled "Formation and Maturation of the Human Sternum," provided a testing of Ashley's (1956) results. Although McCormick and Nichols sample was smaller than Ashley's and restricted to fetal and newborn specimens it provided better evaluation of early ossification by means of ultra-high resolution radiography. The observations reported by McCormick and Nichols agree for the most part with those reported earlier by Ashley, however there were some disagreements.

The McCormick and Nichols study included 100 sequential fetal and newborn sterna. The sterna which were examined as "chest plates consisting of the sternum, costal cartilages, ventral rib ends, and medial clavicular ends with soft tissues attached, were X-rayed in a radiographic unit capable of high resolution radiographs.

From the radiographic analysis, they reported that "one or more minute areas of sternal mineralization were demonstrable in all fetuses over 24 weeks gestational age" (McCormick and Nichols 1981:324). They also found that the youngest case examined with demonstrable mineralization was 21 weeks gestational age. In agreement with Ashley, McCormick and Nichols noted that the size, number and shape of foci of sternal mineralization varied widely even within narrow age and weight ranges.

The authors (McCormick and Nichols 1981) also reported that 94% of the time the developing manubrium was the first demonstrable area of mineralization, and was usually proceded by a second center of ossification in the first sternebra. They also state that the fourth mesosternal ossification center often never formed. As for relative size differences between the manubrial center and the mesosternal centers, they found some variation, with the manubrial center being typically larger. Similarly, they noted that adjacent mesosternal areas of ossification often varied greatly in size.

In observations of the number of ossification centers in the developing manubrium and sternebrae, McCormick and Nichols reported that manubrium most often developed from a single center of ossification, but in certain cases 10% arose from two or more unequal centers (McCormick and Nichols 1981:324). Some or all of the sternebrae arose from paired (34%) or even multiple ossification centers, although single centers were observed 46% of the time. The maximum number of centers of ossification as noted by the authors, developed by the gestational age of 38 to 42 weeks, and in one fetus, totaled 13 centers.

Concerning the fusion of adjacent centers of ossification, McCormick and Nichols found it to occur early at a gestational age of 30 weeks. They noted that fusion was "either side to side or cephalad to caudad" and "in general ossification centers developed from rostral to caudal" (McCormick and Nichols 1981:324). The final or "adult" sternum form as describe by the authors, being that of a manubrium,

body (composed of three to five sternebrae), and the ossified xiphoid was not seen for many years following birth, with the xiphoid being the last to ossify. They noted that none of the 100 fetal sterna examined displayed ossification centers in the xiphoid.

McCormick and Nichols grouped each sternal specimen into one of the "basic" types as described by Ashley. They found that 46% of their specimens could be classified as Type I, 30% as Type II, 4% as Type III and that no Type IV specimens were encountered. However 20% of their specimens had "irregular" or "intermediate" patterns of ossification making it impossible to classify into one of the "basic" types (McCormick and Nichols 1981:327).

McCormick and Nichol's study provided a better insight into early sternal development than did Ashley's 1956 work because of the advanced radiographic technique which allowed more accurate determination of the developing ossification centers.

There are several differences between the study conducted by McCormick and Nichols (1981) and this dissertation research. One major difference is that the present study included a much larger sample size as well as pre- and postpubertal individuals. This study included data on the degree of fusion between sternal segments and fusion anomalies and the relationship of age to sternal ossification. This investigation study went a step further than that of McCormick and Nichols (1981) in examining sexual and racial dimorphism in relation to developmental ossification of the sternum.

While there are differences in this study from that of McCormick and Nichols, similar observations on the percentage of Ashley's sternal types (Ashley 1956) and the appearance of sternal ossification centers as observed in this sample allowed confirmation of McCormick and Nichols earlier study.

The main objective of this dissertation research is to provide further insight into the clarification of the developmental ossification of the human sternum in relation to the "adult form." Another goal of this study is to determine if age, sex and race differences are observable in the developing sternum. Also the cumulative results of this investigation are to be compared with earlier studies so as to confirm or reject prior observations and expound on areas which were not discussed in those studies. With a better understanding of sternal development it may be possible to develop methods for aging and sexing subadults based on sternal ossification. Although other methods are available for aging subadults no method presently exists for sex determination.

CHAPTER II

MATERIALS AND METHODS

Specimens and Collection of Data

The specimens utilized in this study were the "chest plates" consisting of the sternum, costal cartilages, ventral rib ends, and medial clavicular ends of 479 autopsy subjects from the University of Texas Medical Branch at Galveston. Of the 479 subjects, 302 were fetuses or newborns ranging in gestational age from 18 to 38 weeks. The remaining 177 subjects consisted of 113 infants ranging in age from one month to 36 months, and 64 subjects subadults ranging in age from four to 19 years. The sex ratio of this population was 268 males to 221 females. There were 233 American Whites, 141 American Blacks, 97 Latin Americans and eight South East Asians.

Upon removal of the intact chest plate at autopsy each specimen was X-rayed in a Faxitron 43805N closed X-ray system. This particular device is capable of producing ultra-high resolution radiographs. These "chest plate" specimens were individually X-rayed at 20-25 kV peak at 2.5 mA for 1.8-2.0 minutes with Kodack X-Omat TL film "Ready Pack." A picture of the Faxitron unit used in this study if shown in Figure 2, Appendix.

Data concerning the age, sex, race and contributing cause of death was recorded for each subject. The gestational ages of the fetal and newborn subjects were estimated based on crown-rump length and head circumference (Moore 1973:71-84), physical appearance of

skin, ears, breast tissue, and genitalia (Dubowitz and Dubowitz 1970:1-10) and (Finnstrom 1977:601-604) development of cerebral gyri and fissures (Larroche 1977:319-327), and microscopic appearance of the brain, lungs, kidneys, liver and genitalia (Valdes-Dapean 1979). Data also included in this study on the fetal and newborn subjects were weight, crown-rump length, crown-heel length and head circumference. Complete autopsy information and placental examination reports were made available through the Department of Pathology, University of Texas Medical Branch at Galveston.

Data collection from each sternal radiograph consisted of recording the number of ossification centers in the manubrium and each sternebra 1-5 and xiphoid. In addition to the number of ossification centers, the degree of fusion between the ossification centers in the manubrium and each sternebra were noted. Also the degree of fusion between the manubrium and the first sternebra and between each sternebra segment (1-2, 2-3, 3-4). The degree of fusion was semi-quantitatively graded as being either 0, 1, 2 or 3. A grade 0 fusion represented no fusion or contact between adjacent ossification centers. Grade 1 fusion was defined as border contact between adjacent ossification centers and grade 2 fusion was unionization of two adjacent ossification centers in which the unionization was observed as "pinched" with a distinct line of fusion. Grade 3 fusion was defined as unionization of two adjacent ossification centers without an observable line of fusion and minimal "pinching" at the contact boundary. Figure 3, Appendix, illustrates the four grades of

fusion between adjacent ossification centers as observed in sample specimens.

Methods of Data Sorting and Analysis

Visual examination of each of the 479 sternum radiographs were made in order to collect data on the various criteria previously mentioned. These data in turn were recorded on a TRS-80 color computer employing a sternum file program written by Dr. J. H. Stewart, a former resident in pathology at the University of Texas Medical Branch. Later these files were re-assembled and down-loaded to the IBM main frame computer system at the University of Tennessee, Knoxville. Sorting and statistical analysis of the data was performed using various "SAS" procedures *Statistical Analysis System,* (Ray 1982). The complete coded data for each of the 479 individuals was formulated into two separate computer files, one file (File 1) for initial recording and sorting of data and a second file (File 2) for statistical analysis of data. *File 1* and *File 2* are found in Table 1 and 2 respectively, Appendix.

The coding used in formating *File 1* are as follows: *AUTOP,* represented by a five digit number noted the year and autopsy case number of each individual. *AGE,* represented by a two digit number and a single letter noted the age by day, month or year. *GA,* represented by a two digit number, noted the gestational age in weeks of the individual, which applied only to newborns and fetus. *R* and *S* represented by a single letter noted the race and sex of the individual respectively. *Weigh,* represented by a four digit number

noted the weight of the individual in kilograms, this only applied to newborns and fetus. The codes CR, CH and HC were each represented by a two digit number, noting the crown-rump length, crown-head length and head-circumference in centimeters, respectively, these criteria also applied only to newborns and fetuses.

The number of ossification centers in the sternum was represented by the code MX which was a seven digit number, noting the number of ossification centers as observed in the manubrium, sternabra 1, sternabra 2, sternabra 3, sternebra 4, sternabra 5 and xiphoid. In Table 1, Appendix the code MX is shown in its expanded form M12345X.

Also shown in Table 1, Appendix, is the code ABCDEFGHIJK, which was represented by an eleven digit number noting the semi-quantitative degree of fusion of adjacent centers of ossification in (A) the manubrium, (B) the manubrium and sternebra 1, (C) sternebra 1, (D) between sternebra 1 and 2, (E) sternebra 2, (F) between sternebra 2 and 3, (G) sternebra 3, (H) between sternebra 3 and 4, (I) sternebra 4, (J) between sternebra 4 and 5, (K) xiphoid. The code MD represented by two letters is an abbreviation of the cause of death or medical disorder in each individual. The diseases or conditions contributing to death are listed by code and non-abbreviated form in Table 3, Appendix.

The coding in formating File 2 are as follows: AUTOP, represented by a five digit number noted the year and autopsy case number of each individual. AGE, represented by a two digit number noted the age by weeks post-conception (0 weeks being term birth: 38

weeks gestation). R, represented by a single digit number noted the race of each individual (1=White, 2=Black, 3=Latin, 4=Asian). S, represented by a single digit number noted the sex of each individual (1=Male, 2=Female).

The code TO in File 2 was represented by a two digit number (1 through 13) note the total number of ossification centers observed in each sternum. MX, represented a seven digit number, noted the total number of ossification centers as observed in the manubrium, sternabrae 1, sternabrae 2, sternabrae 4, sternabrae 5 and xiphoid. In Table 2, Appendix, the code MX is shown in its expanded form M12345X. Also shown in Table 2, Appendix, is the expanded code ABCDEPG, which was represented by a seven digit number noting the single number of ossification centers (multiple centers in each segment be count as only one) observed in the manubrium, sternabra 1 through 5 and xiphoid. The abbreviated form of the previous noted code was MK. Z, represented by a single digit number (1 through 6) noted the total number of single ossification centers in the sternum as previously described.

After collection and computer entry of the data, File 1 was sorted utilizing the SAS "Sort Procedure" (Ray 1982:771-781). The parameters for the sort routines are as follows: (MX by GA) total ossification pattern of the sternum by gestational age, (MX by AGE) total ossification pattern of the sternum by age year, day or month, (MX by R) total ossification pattern of the sternum by race, (MX by S) total ossification pattern of the sternum by sex, along with a second

sorting by sex including gestational age (MX by S GA), and age year, day or month, (MX by S, AGE).

After computer sorting, the samples were divided into seven basic age groups, those being fetal and newborns, gestational ages 18 to 42 weeks, infants ages one to 36 months, children four to six, seven to nine, pre-adolescents 10 to 12, early adolescents 13 to 15, late adolescents 16 to 19 years. Breakdown by age, sex and race were further tabulated for each of the seven major age groupings.

From the previous sort routines additional sorting consisting of defining all possible MX types by age groups and calculating the percentages of each MX type was conducted. Also the possible number of ossification centers in the manubrium, sternabra 1, 2, 3, 4 and 5 were calculated as to their occurrence. The percentage of Ashley's Type I, II, or Type III classifications, were also calculated for each major age group. General observations on the degree of fusion between ossification centers and certain anomalies of fusion and sternal patterning were also recorded in this study.

File 2 which contained reformated sternum data was analyzed utilizing two SAS procedures, GLM "general linear models procedure" (Ray 1982:139-199) and PLOT "basic plot procedure" (Ray 1982:629-655). In addition to the linear regression procedure, covariance analysis was performed using the "SAS" GLM procedure to determine sex differences after age adjustment. Data contained in File 2 were also analyzed as to the total number of ossifiction centers (TO) and single

centers of ossification (Z) (observing multiple centers of ossification in each segment as only one) vs age, sex and race.

CHAPTER III

PATTERNS OF STERNAL OSSIFICATION IN FETAL AND NEWBORNS, GESTATIONAL AGES 18 to 38 WEEKS

This sample consisted of 302 fetal and newborns ranging in gestational age from 18 to 38 weeks. The male to female ratio was 167 males to 135 females, and the racial breakdown was 148 American Whites, 90 American Blacks, 58 Latin Americans and 6 East Asians. Out of this group 99 individuals died as the result of trauma or cause was unknown. The remaining 203 individuals from which sternal radiographs were made died as the result of a particular disease or condition.

Number of Ossification Centers

The ossification patterns as observed radiographically in this group exhibited much variation, however the majority of them could be classified as to one of the four types established by Ashley (1956). Specimens which could not be classified as to type and represented "indeterminate" patterns are the result of what Ashley termed "supernumary" centers. Ashley, as well as McCormick and Nichols (1981), pointed out that in general, the earlier the age of the fetus the greater the difficulty in placing it in a type group. Figures 5 and 6, Appendix, illustrate an example of "supernumary" centers of ossification.

From the radiographs, 73 different ossification patterns were observed. These 73 possible ossification patterns along with the percentage of occurrence are given in Table 4, Appendix. The most

common pattern, which was found in 25% of the individuals, was classified as an Ashley's Type I, that being a single center of ossification in the manubrium, with single ossification centers in sternebra 1 and 2. The second most common pattern was found in 11% of the individuals, and was classified as an Ashley Type II, that being a single ossification center in the manubrium, with the first and second sternebra ossifying from a single center, with the third sternebra having two centers of ossification. The third most common pattern was found in 10% of the individuals, and was classified as an Ashley Type I.

The greatest number of ossification centers observed in the manubrium was four. The greatest number of centers observed in sternebra 1, 2, 3, and 4 were three, four, three, and five respectively. Table 5, Appendix, shows the possible number of ossification centers in each section of the sternum and the percent of occurrence as observed in this study group. It must also be noted that no centers of ossification were observed among this age group in either the 5th sternebra or xiphoid.

The youngest case in which demonstrable mineralization was observed was 21 weeks' gestational age, the sternal radiograph of this individual is shown in Figure 4, Appendix. It was found that the maximum number of ossification centers in the sternum developed by 38 to 42 weeks. One specimen, a 38 week fetus, had a total of 13 ossification centers in the sternum (Figure 5, Appendix). The absence

of any ossification in the sternum was seen in a total of 16 specimens with none being over the gestational age of 38 weeks.

The first demonstrable area of mineralization occurred 94% of the time in the manubrium, however four individuals were found to present ossification centers in the sternabra segments with no manubrial center of ossification (Figures 6 and 7).

Development of the manubrium in most cases arose from a single center of ossification, however 21% were found to develop from two or more centers. In reference to the sternebrae, 50% were found to develop from single ossification centers and 21% from two or multiple ossification centers. Classification of the sternum samples into one of the four "basic" sternum types was conducted. The percentage of sternum Type 1 as observed in our population was 42%. Type 2 and 3 were observed occurring in 28% and 3% respectively. The Type 4 sternum pattern was not observed in any of the 302 sterna evaluated.

Observations on the Degrees of Fusion and Anomalies

Fusion of adjacent centers of ossification was observed to be variable. Fusion of adjacent centers was observed to occur as early as 29 weeks, with a grade 1 fusion. At gestational ages of 30 weeks upwards fusion of adjacent centers was more common and of grade 2 or higher.

One anomaly observed was the early stage of fusion between the manubrial ossification center and sternabra 1. This highly premature fusion was observed in four cases, with a grade 1 fusion. One of the individuals, a pituitary dwarf, also exhibited what I termed

"snowflake" ossification centers. This "snowflake" or irregular shaped ossification centers, was seen in other individuals classified as achondroplastic or pituitary dwarfs. A radiographic print of one individual illustrating the grade 1 fusion between the manubrial ossification center and sternebra 1, is shown in Figure 8, Appendix.

Determination of other anomalies in the study group did not reveal any other occurrences, however it was difficult to judge due to "supernumerary" centers and the great variation in ossification patterns among this group. Another example of sternal development is in a 37 week old fetus shown in Figure 9, Appendix. Figures 10, 11 and 12, Appendix, show various sternal ossification patterns as viewed from dried sternum specimens of fetus and newborns.

CHAPTER IV

PATTERNS OF STERNAL OSSIFICATION IN INFANTS AGES 1 TO 36 MONTHS

This study group consisted of 113 infants ranging in age from 1 to 36 months. The male to female ratio was 59 males to 54 females, and the racial breakdown was 51 American Whites, 36 American Blacks and 26 Latin Americans. Out of this group 24 individuals died as the results of trauma or unknown causes. The remaining 89 individuals from which sternal radiographs were made died as the result of a particular disease or condition.

Number of Ossification Centers

The ossification patterns as observed radiographically in this group, exhibited variation, but to a lesser extent than seen in fetus and newborn material. This is most likely due to the more mature ossification centers and the decrease in "supernumerary" centers. The majority of these patterns could be classified as to one of the four types set forth by Ashley (1956), however some specimens could not be classified as to type because they were intermediate patterns.

From the radiographs, 63 different ossification patterns were observed. These 63 possible ossification patterns along with the percentage of occurrence are given in Table 6, Appendix. The most common pattern, which was found in 14% of the individuals, was classified as an Ashley's Type I, that being a single center of ossification in the manubrium, with single ossification centers in

sternebra 1 and 2. The second most common pattern was found in 7% of the individuals, was classified as an Ashley Type II, or a single ossification center in the manubrium, and the first and second sternebra ossifying from a single center, with the third sternebra having two centers of ossification. The third most common pattern actually consisted of two patterns and was found in 8% of the individuals. Both patterns although not exactly configured as an Ashley Type I, would, with further development, meet the classification criteria.

The greatest number of ossification centers observed in the manubrium was six (including "supernumerary centers"). The greatest number of centers observed in sternebra 1, 2, 3, 4, and 5 were four, six, three, three and one respectively. Table 7, Appendix, shows the possible number of ossification centers in each section of the sternum and the percent of occurrence as observed in this study group. It must also be noted that no centers of ossification were observed among this age group in the xiphoid.

Demonstrable mineralization was observed in all 113 children, and in no case was their absence of an ossification center or centers in the manubrium. A single center of ossification in the manubrium was observed in 68% of the individuals examined. Figures 13 through 26, Appendix, show various examples of the ossification patterns observed in this group.

The greatest number of ossification centers observed in the sternum samples examined was 12. In reference to the sternebra,

approximately 69% were found to be developing from single ossification centers and 30% from even or multiple ossification centers. Classification of the sternum samples into one of the four "basic" sternum types was also conducted. The percentage of sternum Type 1 as observed in this population was 39%. Type 2 and 3 were observed occurring in 51% and 73% perspectively. The Type 4 sternum pattern was not observed in any of the 113 sterna evaluated.

Observations on the Degrees of Fusion and Anomalies

Fusion of adjacent centers of ossification were observed to be variable, but with a greater frequency over that of the newborn and fetus sample. Of the study population 48% exhibited some degree of fusion between adjacent ossification centers and approximately 19% of the individuals examined had a grade 3 fusion in one or more segments.

The early stage of fusion between the manubrial ossification center and sternebra 1, along with premature fusion of the adjacent sternebrae was not common. Three specimens exhibiting this irregular fusion were found within the study group. Two individuals, a 16 month old and a 5 month old infant, presented a grade 2 fusion between the developing manubrium and sternebra 1 with grade 3 fusion between sternebra segments. The third individual possessed a grade 1 fusion between the manubrium and sternebra 1, with grade 2 fusion between sternabra segments.

One individual possessed a sternal foramina, which was visible in the cartilage of the lower sternal body. Although the foramen is quite large in size, it will most likely be filled in to a greater

degree once ossification centers develop and form around it. Figure 20, Appendix shows the cartilagenous foramen as observed in a 1 month old Black female.

CHAPTER V

PATTERNS OF STERNAL OSSIFICATION IN CHILDREN 4 TO 6 YEARS

This study group consisted of 17 children varying in age from 4 to 6 years. The male to female ratio was 12 males to five females, and the racial breakdown was nine American Whites, six American Blacks and two Latin Americans. Out of this group, four individuals of the 17, died as the result of trauma or cause was unknown. The remaining 13 individuals from which sterba were examined died as the result of a particular disease or condition.

Number of Ossification Centers

The total ossification pattern, as observed radiographically in this group varied less in than the previous earlier age groups. "Supernumerary" centers of ossification were not observed in this group and larger ossification centers were more prevalent. From the radiographs, 13 different ossification patterns were observed. These 13 possible ossification patterns along with percentage of occurrence are given in Table 8, Appendix.

The greatest number of ossification centers observed in the sternum as a whole was 10. The radiograph of the 4 year old Black female in which these 10 ossification centers were observed is shown in Figure 31, Appendix. Maximum number of ossification centers in the manubrium, sternebrae 1 through 5 were 4, 1, 2, 2, 2 and 1 respectively. Table 9, Appendix, shows the possible number of

ossification centers in each section of the sternum and the percent of occurrence. Classification of the sternum samples into one of four "basic" sternum types was also made. The percentage of sternum Type 1 as observed in this population was 51%. Type 2 and 3 were observed occurring in 42% and 0% respectively. Type 4 sternum pattern was not observed in any sternum.

<u>Observations on the Degrees of Fusion and Anomalies</u>

Fusion of adjacent centers of ossification was observed to occur in 11 of the 17 sample sterna examined. In 11 of the sterna, fusion of adjacent centers of ossification was observed with all but one individual exhibiting a grade 2 fusion. No other significant observations on fusion of adjacent centers of ossification in this group were observed (Figures 32-34, Appendix).

CHAPTER VI

PATTERNS OF STERNAL OSSIFICATION IN CHILDREN 7 TO 9 YEARS

This study group consisted of 10 children varying in age from seven to nine years. The male to female ratio was six males to four females, and the racial breakdown was six American Whites, three American Blacks and one Latin American. Out of this group five individuals had died as the result of trauma. The remaining five individuals whose sternums were examined had died as the result of a particular disease or condition.

Number of Ossification Centers

The total ossification pattern as observed radiographically in this group showed variation from individual to individual. From the radiographs, eight different ossification patterns were observed. Only in two of the patterns were there individuals sharing the same pattern. However, classification of these sterna into one of the three Ashley Types could be easily made. Eight individuals had ossification patterns which could be classed as Type I and the other two as Type II. The eight different ossification patterns observed along with their frequency of occurrence are given in Table 10, Appendix.

The greatest number of ossification centers observed in the sternums was seven. Maximum number of ossification centers in the manubrium, sternebrae 1 through 5 were 2, 1, 1, 2, 1, and 1

respectively. The number of centers in each element of the sternum is much smaller than in the earlier age groups particularly the newborn and fetus sample. Table 11, Appendix gives the possible number of ossification centers in each section of the sternum and their frequency of occurrence. As one would expect with increasing age, the ossification centers are larger in diameter with a more squared-off appearance. Also at this age sternum begins to take on the adult form as seen in the conforming of the manubrium to the positions of the jugular, clavicular and costal notches. The manubrium consisted of a single ossification center in all specimens examined with the exception of two individuals. One sternum from an eight year old White male, in which the manubrium still persists as dual centers of ossification, is shown in Figure 35, Appendix.

Two of the sternums examined showed early ossification of the xiphoid. This premature ossification of the xiphoid was observed in a seven year old White male and a nine year old Latin female, whose radiographs are shown in Figures 36 and 37, Appendix.

Observations on the Degrees of Fusion and Anomalies

Observations on the fusion of adjacent centers of ossification was found to be occurring in some form, at one area or another, in all but one individual who exhibited no distinct fusion between centers. In one specimen a grade 2 fusion was observed between the manubrium and sternebra 1.

Another sternum specimen from an eight year old White male, in which the manubrium can still be observed as developing from dual

centers of ossification, presents a small sternal foramina located at the junction of sternebra 2 and 3 (Figure 38, Appendix). No other abnormalities or unusual ossification patterns or fusion were observed in this study group.

CHAPTER VII

PATTERNS OF STERNAL OSSIFICATION IN PRE-ADOLESCENTS 10 TO 12 YEARS

This study group consisted of six pre-adolescents 10 to 12 years of age, with a male to female ratio of 3 to 3. Racial breakdown of this group was five American Whites and one Latin American. Out of this group, three individuals from which sternal radiographs were made, died as the result of trauma. The remaining three individuals whose sternal radiographs were examined, died as the result of a particular disease or condition.

Number of Ossification Centers

From the radiographs, four different ossification patterns were observed. Only in two of the patterns were there individuals sharing the same pattern. Classification of these sterna into one of the three Ashley Types were made. Four of the individuals could be classified as Type I and the other two as Type II. The four different ossification patterns observed along with their frequency of occurrence are given in Table 12, Appendix.

The greatest number of ossification centers observed in the sternums was nine. Maximum number of ossification centers in the manubrium, sternebrae 1 through 5 were 1, 1, 3, 4 and 1 respectively. Table 13, Appendix, gives the possible number of ossification centers in each section of the sternum and their frequency of occurrence. Again as in the previously discussed study group the ossification

centers are much larger and at this age level approach the adult form in sternal segments.

Three of the sternums examined, showed early ossification of the xiphoid. The sternal radiographs in which the early xiphoid ossification was observed are from a 10 year old Latin male and a 10 year old White male. This premature ossification xiphoid in the three pre-adolescents are shown in Figures 39 and 40, Appendix.

Observations on the Degrees of Fusion and Anomalies

Observations on the fusion of adjacent centers of ossification, was found to be present in all but one case. The degree of fusion observed in the five sterna was of a grade 2. No premature fusion of the manubrium and sternebra 1 was observed nor was the presence of a sternal foramen seen. Figure 41, Appendix, show the sternal radiograph of an 11 year old White female which was included in the study sample.

CHAPTER VIII

PATTERNS OF STERNAL OSSIFICATION IN EARLY ADOLESCENTS 13 TO 15 YEARS

This study group consisted of 12 adolescents 13 to 15 years of age. The male to female ratio was seven males to five females, and the racial breakdown was four White Americans, four Black Americans, three Latin Americans and one East Asian. Out of this group four had died as the result of trauma. The remaining eight individuals whose sternums were also examined, had died as the result of a particular disease or condition.

Number of Ossification Centers

The total ossification pattern as observed radiographically in this group showed little variation considering the number of single ossification centers. From the radiographs six different ossification patterns were observed. One pattern was shared by five individuals and in another pattern three individuals were observed to have the same pattern. Classification of the sterna by Ashley's Types was also made. Out of the 12 sterna examined 10 could be classified as Ashley's Type I, with the remaining two sterna being classified as a Type II and Type III. The greatest number of ossification centers observed in any of the sterna was six. The greatest number of ossification centers in the manubrium, sternebra 1 through 5 were 1, 1, 2, 2, and 2. Here one center occurs most often and two centers represent an even closer relationship with the adult form. The six

different ossification patterns observed along with their frequency of occurrence are given in Table 14, Appendix. Table 15, Appendix gives the possible number of ossification centers in each section of the sternum and their frequency of occurrence.

Xiphoid ossification was seen in only one specimen from this age group, that being the sternum from a 13 year old White male (Figure 42, Appendix). Also observed was the intermediate formation of sternal foramina in the sternum of a 14 year old Latin male. The foramen which was present in the cartilaginous bar of a sternebra, was in the process of being surrounded by ossifying tissue and is shown radiographically in Figure 43, Appendix.

Observations on the Degrees of Fusion and Anomalies

The degree of fusion between adjacent ossification centers as observed in this age group was minimum. The great majority of the earlier ossification centers have previously fused with adjacent centers forming a single manubrium or sternebra. Only in two individuals, in which there were dual or numerous ossification centers present, was fusion occurring. In the case of a 14 year old White female afflicted with cerebral palsy and growth retardation there was premature fusion of the manubrium to the first sternebra and each of the three sternabra were fused to one another. The radiograph of this highly premature fusion is shown in Figure 44, Appendix.

Premature fusion in the sternum has been reported on by several investigators in reference to congenital heart disease and Noonan's syndrome (Hall 1960; Gabrielsen and Ladyman 1963; Hoeffel and Pernot

1981). An even more striking defect was observed in the sternum of a 15 year old Black female suffering from Prader-Willi's syndrome. The sternum of this individual is void of any sternebra segments with only slight traces of calcification of tissues where the sternebrae should normally be. Steiner, Kricum and Shapiro (1976), reported similar observations in individuals with congenital heart disease. Figure 45, Appendix shows the sternal radiograph of the 15 year old Black female and the absence of the mesosternum.

Figures 46, 47, 48, and 49 are sternal radiographs of a 15 year old White female, 13 year old Black female, 13 year old Black male, 14 year old Black male, all of whose sternums were examined in this particular study group.

CHAPTER IX

PATTERNS OF STERNAL OSSIFICATION IN LATE ADOLESCENTS 16 TO 19 YEARS

This study group consisted of 19 late adolescents from 16 to 19 years of age. The male to female ratio was 14 males to 15 females, and the racial breakdown was 10 American Whites, 6 Latin Americans, two American Blacks and one East Asian. Out of this group 10 individuals had died as the result of trauma. The remaining nine individuals whose sternums were examined had died as the result of a particular disease or condition.

Number of Ossification Centers

The total ossification pattern as observed radiographically in this group showed less variation from individual to individual than observed in any of the previously discussed age groups. From the radiographs a total of seven different ossification patterns were observed. Three of the patterns observed, were each shared by five individuals. In classifying these 19 sterna into Ashley's Types it was found, that all but two could be classified as Type I, with the other two being Type II specimens. The seven different ossification patterns observed along with their frequency of occurrence are given in Table 16, Appendix. Table 17, Appendix, shows the possible number of ossification centers in each segment of the sternum and the frequency of occurrence in late adolescents, 16 to 19 years.

An examination of the sternum from a 16 year old White female, found only two sternebrae, those being number 1 and 2. This rarity was not observed in any other individuals except fetal and newborn material in which case the lower sternebrae had not yet begun to ossify. One might expect to see the deletion of the sternebra 3 in individuals with certain diseases as pointed out earlier, however this individual whose sternal radiograph can be seen in Figure 50, Appendix was considered to be of normal development.

Observations on the Degrees of Fusion and Anomalies

Observations on the degree of fusion between sternebrae or dual centers of ossification in this group was found, quite interesting. In six of the sterna examined there was some degree of fusion between the manubrium and the first sternebra. Two individuals exhibited grade 1 fusion and three others exhibited a grade 2 fusion.

Of particular interest was a 19 year old Black female born with spinal bifida. The sternum of this individual was totally ossified with complete fusion of all sternebra segments including fusion between sternebra one and the manubrium. In addition to the premature sternal fusion, a sternal foramen was located in the lower third of the sternal body. The radiographic plate of this individual showing the premature fusion and sternal foramina is shown in Figure 51, Appendix. Figures 52 and 53, Appendix, show the actual chest plate prior to skeletalization, in which the location of the sternal foramen is marked. After the specimen was X-rayed it was skeletalized to

allow gross examination, Figure 54, Appendix, shows the skeletalized specimen.

CHAPTER X

ANALYSIS OF AGE, SEX AND RACE DIFFERENCES IN DEVELOPMENTAL OSSIFICATION

It was observed in this study, that the formation of ossification centers in the developing sternum varied with age. In order to examine this relationship, sorting along with statistical analysis of the sternal data were performed.

Sex and racial differences in the number of ossification centers were not apparent by visual examination so statistical methods were used to determined if possible relationships existed. Preliminary ploting of AGE vs TO (total number of ossification centers), found individuals older than 150 weeks of age to exhibit marked variability, due to multiple centers of ossification in younger individuals and differences between the final number of sternebrae in older individuals. Since marke variability was observed in individuals older than 150 weeks, they were not included in the following analyses.

Analysis of Age Differences

In examining the relationship between age and the number of ossification centers in the sternum two "SAS" Statistical Analysis System, procedures were employed (Ray 1982). The first procedure consisted of a basic sort routine which was run on sternum File 2. Sorting of the study population was done on the bases of AGE to TO, with all ages being rounded to ten week intervals. The results of

this procedure included the following: the mean, standard deviation and variance of TO for each age group; number of individuals in each age group; and the maximum and minimum TO values.

The previously described procedure was also used to sort the study population on the bases of AGE vs Z (single centers of ossification; multiple centers in each sternal segment being viewed as only one). This was initiated to provide another means of determining if any relationship existed.

The second procedure used in examining age differences in TO was the "SAS" GLM (general linear models), which is a linear regression analysis. Prior to running the regression analysis, all ages were increased by thirty-eight (38 weeks being term birth) so as to delete negative age values which represented pre-natal ages. Conversion of all ages to positive values allowed further conversion of the ages by the log of ten, which was necessary in running the regression analysis.

Analysis of Sexual Dimorphism

Examining sexual dimorphism on the bases of TO (total number of ossification centers) as observed in the sternum, three "SAS" procedures were employed. The first procedure consisted of an identical sort routine as previously applied for age, with the addition of sex as a second variable.

The same "SAS" sort procedure was run comparing Z values vs AGE by sex.

A second "SAS" procedure used in examining sexual dimorphism in relation to TO was the GLM (general linear model). This regression analysis was applied to the data in sternum File 2, so that a regression model could be formulated for each sex as well as determine the significance of age to TO in each sex. As in the previous GLM procedure the ages in File 2 were increased by the addition of 38 and converted by the log of ten.

Plots of log TO vs log AGE by sex were produced for both males and females using the "SAS" PLOT procedure. Upon completion of the plots, regression lines were plotted for males and females using the linear regression formula (bo + b_1 X_1) and the intercept and slope values. Four points were plotted for each sex being the log AGEs 1.25, 1.45, 1.65, 1.85, 2.05 and 2.25.

A third "SAS" procedure used in examining sexual dimorphism in relation to TO was the GLM, in which the analysis of co-variance was performed. In the co-variance analysis both sexes were adjusted for age. Also included in this statistical procedure was the test of LSMEAN (least squares means), in which the mean values for the regression of each sex were adjusted to the same age and tested for significance.

Analysis of Racial Variation

Analysis of racial variation in relationship to TO (total number of ossification centers) was prepared emplying two "SAS" routines, those being the SORT and GLM (general linear models) procedures including analysis of co-variance and LSMEANS (least square means).

Two sort routines were used to sort the date in File 2. One routine sorted the study population on the bases of TO, AGE and R (race). A second routine was used to sort the sample on the bases of Z, AGE and R.

Final examination of racial variation in relation to TO, was performed with the "SAS" GLM routine: analysis of co-variance and LSMEANS. As in the previous GLM routines the ages in File 2 were increased by the addition of 38 and converted by the log of ten, prior to analysis. In the first step of the analysis regression values were calculated so as to test the regression slopes for heterogenity of log AGE by R (race). Secondly analysis of coyariance was employed to test for heterogenity among racial groups, with the means adjusted by log AGE. The last step of analysis was to examine the least square means (LSMEANS) of log TO vs R, with adjustment of the means by log AGE.

CHAPTER XI

RESULTS AND CONCLUSIONS

Summary of Observations on Patterns of Sternal Ossification

This study of developmental ossification was observed in 479 individuals ranging in age from 18 gestational weeks to 19 years, provide much insight into the development of the human sternum. I had not previously realized the complexity and tremendous variability which could occur during the developmental process.

Developmental ossification patterns in fetus and newborns was observed to exhibit the most variability. Seventy-three different patterns of ossification were seen in this group. Utilizing Ashley's classification of "basic" sternum types, the majority of the fetal and newborn sterna could be typed. Approximately 42% of the sterna could be classed as Ashley's Type I, with 28% and 3% being classed as Types II and III respectively. Due to the irregular ossification and transitional fusion of "supernumerary" centers of ossification 27% of the specimens examined could not be typed. Ashley's rare Type IV sternum pattern was not observed in any of the specimens examined.

About 25% of the individuals in the fetus to newborn group shared the same total ossification pattern, that being a single center of ossification in the manubrium and a single center in sternebra 1 and 2. The greatest number of ossification centers from which the manubrium developed was four. In none of the cases examined were there centers of ossifications in either the fifth sternebra or

xiphoid. The youngest case in which demonstrable sternal ossification was observed was 21 weeks gestational age. Maximum number of ossification centers were found to be present by 38 to 42 weeks gestational age. The number of ossification centers in the sternum ranged from 1 to 13. Absence of ossification in the sternum was observed in 16 individuals with none being over the gestational age of 38 weeks.

Concerning the development of the manubrium, it was found that the manubrium arose from a single center of ossification in 79% of the specimens examined. In reference to the sternebrae, 50% were found to develop from single centers of ossification, with 21% developing from dual or multiple centers. Only 15% of the sterna from the fetus and newborn group exhibited ossification in the fourth sternebra.

Variable fusion of adjacent centers was observed to occur as early as 29 weeks gestation, with fusion of a grade 2 or higher after 30 weeks of age. A highly premature fusion of the manubrial center to the first sternebra was also observed. Although the degree of fusion observed in four different individuals, was only a grade 1 fusion, it still was a rarity. Determination of particular anomalies in this group was difficult due to the tremendous variation of patterns and "supernumerary" centers, however individuals who were classified as metabolic dwarfs were observed to exhibit a "snow-flake" appearance of ossification. This "snowflake" appearance consisted of very irregular and thread-like ossification centers thus giving the appearance of large snowflakes.

Developmental ossification patterns in the age group 1 to 36 months, were similar to those of the fetal and newborn group. In this group, 63 different ossification patterns were observed with the most common pattern being found in 14% of the individuals. This particular pattern consisted of a single center of ossification in the manubrium and single centers in sternebrae 1, 2 and 3. The manubrium was observed to develop from one to six centers of ossification, with 69% developing from a single center. Total number of ossification centers in the sternum as a whole ranged between three and twelve.

Approximately 39% of the sterna could be classed as Ashley's Type I, with 51% and 3% being classed as Type II and III respectively. Differing from the fetus and newborns, certain individuals in this group exhibited centers of ossification in the fifth sternebrae.

Fusion of adjacent centers of ossification was also variable in this group, however 48% of the sternums examined, exhibited some degree of fusion between adjacent ossification centers and approximately 19% of the individuals had grade 3 ossification in one or more segments. Premature fusion of sternebra, one to the manubrium, and fusion of adjacent sternebrae was observed in three specimens. One individual in this study was observed to possess a sternal foramina, which was visible in the cartilage of the lower sternal body.

Among children 4 to 6 years of age, the total ossification pattern was found to be less variable than the two earlier age groups examined. Thirteen different ossification patterns occurred in this

group, with the most common patterns consisting of single ossification centers in the manubrium and sternebrae. The greatest number of ossification centers in a single sternum was 10. The manubrium in this group consisted of a single center of ossification in 65% of the individuals. Some individuals in this group were observed to have ossification centers in sternebra 4 and 5.

Fusion of adjacent centers of ossification occured in some form in 11 of the 17 sterna examined, with 10 of the individuals exhibiting grade 2 fusion. No significant forms of premature fusion were found in this group.

Among children 7 to 9 years of age, eight different ossification patterns were observed. Classification of these sterna into one of the three Ashley Types, found eight sterna to be classified as Type I and two as Type II. The greatest number of ossification centers occurring in any sternum was seven. The number of ossification centers in each element of the sternum was found to be smaller than any of the previous age groups discussed.

In the manubrium, all but two individuals had single centers of ossification. As one would expect with increasing age, the ossification center(s) were much larger and appeared more squared-off. The adult configuration of the sternum begins to take place at this time (7 to 9 years of age) as seen in the conforming of the manubrium to the positions of the jugular, clavicular and costal notches. Early ossification of the xiphoid was observed also in two individuals, a seven and nine year old.

Fusion between adjacent centers of ossification centers was found to be occurring in all but one individual. In one specimen there was fusion between the manubrium and sternebra one of a grade 2. The only significant observation concurring irregularities was the presence of a small sternal foramen in an eight year old.

Among pre-adolescents ages 10 to 12 years, four different ossifications were observed. Classification of these sterna into Ashley Types, found four individuals to be Type I and the other two as Type II. The greatest number of ossification centers seen in any sternum was nine. All six sterna from this age group had single centers of ossification in the manubrium. As in the previous group the centers which are now segments of the sternum were larger and more adult in form. Three of the six sternums examined showed early xiphoid ossification.

Fusion of adjacent centers of ossification was found to be present in all but one sternum sample. No examples of premature fusion of the manubrium and sternebra 1 were observed nor were any abnormalities or irregularities found.

Observation of developmental ossification in adolescents ages 13 to 15 years of age, revealed six different ossification patterns. The most common pattern, exhibited by five individuals, consisted of a single osseous element in the manubrium, sternebra one, two and sternebra three. This particular pattern is the most like the final adult form. Out of the 12 sterna examined in this age group 10 could classified as Ashley's Type I, with the remaining two sterna being

Type II. The greatest number of osseous elements observed in any single sternum was six. In all individuals the manubrium consisted of a single osseous element.

Xiphoid ossification was seen in only one individual between the ages of 13 and 15 years. An intermediate sternal foramen was observed in a 14 year old in which the foramen was in the process of being surrounded by ossifying tissue. Fusion between adjacent centers in this group was minimum, this due to the fact that earlier ossification centers have already under gone fusion forming single elements. Premature fusion of the total sternum was observed in a 14 year old who was afflicted with cerebrial palsy. Another highly unusual specimen observed was from a 15 year old suffering from Prader-Willi's syndrome. This individual's sternum consisted of only a manubrium.

Observation of the developmental ossification patterns in late adolescent ages 16 to 19 years, showed less variation between individuals than all previous groups. There were seven different ossification patterns observed in this group, of which three patterns were shared by five individuals each. The greatest number of ossification elements observed in individuals between 16 and 19 years of age was six. An observation to be noted was the presence of only two sternebrae in a 16 year old giving the sternum a dwarf appearance, however this was not the result of disease or growth retardation as the individual was considered normal and had died as the result of trauma.

Fusion among adjacent centers of ossification was seen in every sample with 47 of the sterna having a grade 3 fusion present in one or more areas. Six of the individuals from this study sample exhibited fusion between the manubrium and sternebra one. In one 19 year old afflicted with spinal bifida, there was complete sternal fusion and a large sternal foramen.

From the previous descriptive observations, it is evident that developmental ossification is a complex process in which some variability exists. The process of ossification appears to begin at approximately 18 to 21 weeks of gestation. The manubrium is the first segment of the sternum to ossify followed by ossification of the first sternabra and lower sternebra segments. Formation of the manubrium consists of a single center of ossification in the great majority of individuals, where as the developing sternebrae consist of two or more centers. As gestational age increases so does the number of ossification centers, with the maximum number being reached by the gestational age of 38 to 42 weeks.

Fusion of adjacent centers of ossification begins at a gestational age of approximately 29 to 30 weeks. The typical pattern of fusion occurred either from side to side or cephalad to caudad. Continuing fusion of the centers of ossification up through early and late adolescents produced the "adult" sternal form of a manubrium, body (consisting of three to five sternebrae), and ossified xiphoid.

Although the previously outlined development of sternum can be considered normal or typical, there are some inconsistencies. These

inconsistencies or anomalies which for the most part consist of premature fusion of sternal segments, can be encountered in individuals who are considered to be of normal growth and development.

Correlations of Age, Sex and Race to Developmental Ossification

The results of the various statistical analysis on the relationship of age, sex and race to developmental ossification of the sternum, provided new information as well as new questions. In examining the mean TO (total number of ossification centers in a sternum) values as given in Table 18, Appendix, it is apparent that with the increase of age, the number of ossifications centers in the sternum also increases. This increase of ossification centers begins at 18 weeks gestation and peaks at approximately 60 weeks post-natal, after which there is a leveling off, followed by some fluctuation. A graphic representation of the increase of TO with age, is shown in Figure 55, Appendix.

Examination of mean Z (single centers of ossification: reguarding multiple centers as only one), values in relationship to age as given in Table 19, Appendix, a similar pattern was evident although the increase of Z with age was greater. This increase of Z with age can also be viewed graphically in Figure 56, Appendix. Results of the Anova test for regression of log TO vs log AGE are as follows:

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR- F	R-SQUARE	C.V.
MODEL	1	4.43014912	4.43014912	109.40	0.001	0.210222	27.5245
ERROR	411	16.64352054	0.04049518				
		21.07366967					

The predicted F-value of .0001 with 1 degree of freedom as given above is highly significant, thus confirming a linear relationship of log TO with log AGE. The following regression formula was calculated for testing the model:

Log TO = .4924 + Log AGE x -.0557

Analysis of sexual dimorphism found TO to be greater in males than females at most ages. This finding is somewhat apparent when examining the mean TO values given in Table 20, Appendix, but is better visualized in the graphic representation shown in Figure 58, Appendix. Results of the calculated mean Z values in relationship to age and sex as given in Table 21, Appendix, and graphically represented in Figure 58, Appendix, show this variation to a lesser degree.

Further detailed analysis found the difference between males and females in relation to TO, to be statistically significant. Results of the Anova test for regression of Log TO and log AGE for males are shown below:

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR- F	R-SQUARE	C.V.
MODEL	1	3.05419227	3.05419227	75.15	0.0001	0.254608	26.9366
ERROR	220	8.94145179	0.04064296				
CORRECTED TOTAL	221	11.99564406					

Examination of the calculated results for males by age shows a predicted F-value of .0001 with 1 degree of freedom. The T-value given for the regression model slope is also .0001. Both the F and T values are statistically significant thus confirming a difference in TO between age groups of males. Identical F and T values were also found for females from regression analysis by age.

The complete regression results for females are shown below:

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR- F	R-SQUARE	C.V.
MODEL	1	1.58857306	1.58857306	40.87	0.0001	0.177811	27.7282
ERROR	189	7.34548061	0.03886498				
CORRECTED TOTAL	190	8.93405367					

The following regression formulas allowed plotting of regression lines for males and females by age:

Males Log TO = .5908 + Log AGE x -.1916

Females Log TO = .4089 + Log AGE x .5043

The regression lines as plotted from the intercept and slope values for males and females are shown in Figures 59 and 60 respectively, Appendix. Again as in previous analyses the increase of TO with age is seen to occur in both males and females.

Further regression analysis comparing log TO to log AGE by S provided additional information reguarding variation. The full model regression results of log TO vs log AGE, S and log AGE * S interaction are given below:

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR-F	R-SQUARE	C.V.
MODEL	3	4.78673726	1.59557909	40.07	0.0001	0.227143	27.2945
ERROR	409	16.28693240	0.03982135				
CORRECTED TOTAL	412	21.07366967					

Additional examination of sex differences was accomplished by sum of squares analysis in which the independependent variables log AGE, S and log AGE by S were tested for equality of slopes. Results of this analysis gave a predicted F value of .0001, .1035 and .0524 with 1 degree of freedom for log AGE, S and log AGE by S respectively. The predicted F value for log AGE and log AGE by

S are statistically significant with the latter being the least significant. Regression analysis of the variable S alone produced a non-significant value. The complete results of the sum of squares analysis are given below:

SOURCE	DF	TYPE I SS	F VALUE	PR- F	DF	TYPE III SS	F VALUE	PR- F
LAGE	1	4.43014912	111.25	0.0001	1	4.55235394	114.32	0.0001
S	1	0.20586658	5.17	0.0235	1	0.10599971	2.66	0.1035
LAGE*S	1	0.15072156	3.78	0.0524	1	0.15072156	3.78	0.0524

In order to better test the sex differences an analysis of covariance for differences between sexes controlling for age was performed. From the analysis of covariance a predicted F value of .0001 denotes the significant differences between males and females when age is controlled. Complete results of the analysis of covariance are given below:

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR- F	R-SQUARE	C.V.
MODEL	2	4.63601570	2.31800785	57.82	0.0001	0.219991	27.3871
ERROR	410	16.43765397	0.04009184				
CORRECTED TOTAL	412	21.07366967					

Analysis by the sum of squares which tested the independent variables S and log AGE for differences between the adjusted age means, produced a predicted F value of .0240 for S, thus futher confirming the sex differences in relation to TO. Complete results of the analysis of the sum of squares are as follows:

SOURCE	DF	TYPE I SS	F VALUE	PR- F	DF	TYPE III SS	F VALUE	PR- F
S	1	0.14397194	3.59	0.0588	1	0.20586658	5.13	0.0240
LAGE	1	4.49204376	112.04	0.0001	1	4.49204376	112.04	0.0001

Results of the LSMEANS analysis of variation between mean log TO in relation to sex, provides additional support for sexual

dimorphism in which the LSMEANS value for males (.7518) is higher than for females (.7072). Complete results of the LSMEANS analysis are given below:

SEX	LTO LSMEAN	STD ERR LSMEAN	PROB - (T) HO:LSMEAN=0	PROB - (T) HO: LSMEAN1=LSMEAN2
MALE	0.75183069	0.01344237	0.0001	0.0240
FEMALE	0.70702394	0.01449292	0.0001	

Variation among the races examined in this study was found not to be significant. Comparison of the calculated mean TO values for each race by age showed little differences, Table 22, Appendix. Examination of Table 23, Appendix, the mean Z values were also found to be similar for each race in all age groups. The results of the full model regression analysis of log TO vs R are shown below:

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR- F	R-SQUARE	C.V.
MODEL	7	4.81777944	0.68825421	17.15	0.0001	0.228616	27.4029
ERROR	405	16.25589023	0.04013800				
CORRECTED TOTAL	412	21.07366967					

From this regression the predicted F value is .0001 with 7 degrees of freedom. Further analysis employing the sum of squares and tests of significance for independent variables log AGE, S and log AGE by R, show no significant differences. Complete results of this analysis are shown below:

SOURCE	DF	TYPE I SS	F VALUE	PR- F	DF	TYPE III SS	F VALUE	PR - F
LAGE	1	4.43014912	110.37	0.0001	1	0.42425375	10.57	0.0012
S	3	0.21731591	1.80	0.1439	3	0.20553807	1.71	0.1632
LAGE*R	3	0.17031441	1.41	0.2368	3	0.17031441	1.41	0.2368

Analysis of covariance for differences between races controlling for log AGE also failed to show statistical significance. Complete results of this analysis are as follows:

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR - F	R-SQUARE	C.V.
MODEL	4	4.64746503	1.16186626	28.86	0.0001	0.220534	27.4446
ERROR	408	16.42620463	0.04026031				
CORRECTED TOTAL	412	21.07366967					

In examing the sum of squares and tests for independent variables for racial differences between adjusted age means the probabilty of F was calculated as .1449 for R. Again as in all previous regression analyses for racial variation there is no statistical significance. Complete results of the sum of squares analysis are shown below:

SOURCE	DF	TYPE I SS	F VALUE	PR- F	DF	TYPE III SS	F VALUE	PR- F
R	3	0.26693711	2.21	0.0849	2	0.21731591	1.80	0.1449
LAGE	1	4.38052792	108.81	0.0001	1	4.38052792	108.81	0.0001

Final teseting for racial variation, employed analysis of LSMEANS where R was adjusted by log AGE means, showed no statistical significance among racial groups. The LSMEANS values calculated for each race were .7341 for Whites, .7051 for Blacks, .7670 for Latins and .7532 for Asians (Table 24, Appendix).

Conclusions and Discussion

The results of this study have for the most part confirmed the findings of earlier research on the developmental ossification of the human sternum. Additionally, this research has demonstrated the occurence of sexual dimorphism in relationship to the total number of ossification centers in the sternum during pre-natal and early post-natal (birth to 3 years) ages.

Variability in the sternal ossification patterns, as observed in this study were found to decrease with age. Between 18 to 38

weeks gestation, a total of 73 possible ossification patterns were observed and by 16 to 19 years of age only 3 patterns were observed. The greater variability of ossification patterns as observed in fetus and young children is a direct result of normal skeletal growth. Once the maximum number of ossification centers is reached in an individual (by 38 weeks gestation-birth) their number will be reduced by fusion with the progression of age. Statistical analysis also showed that in early sternal development the total number of ossification centers increased with age.

Similar to Ashleys (1956) and McCormick and Nichols (1981) studies each fetal and newborn sternum, was classified as to Ashley "types". The percentage of the four "types" as reported in this study were different than reported by Ashley (1956) but very similar to those reported by McCormick and Nichols (1981). In Ashley's study he reports frequencies of 22, 60 and 18% for Types I, II, and III respectively. McCormick and Nichols reported frequencies of 46, 30 and 18% for the three types, which are very close to the ones reported here as 49, 32 and 5%.

Ashley's frequencies as to sternal "type" in older children and subadults were somewhat different than those found in this study, however these differences could be due to the variations in sample size. The study conducted by Ashley can be cosidered a classic but in many areas of discussion he failed to mention particular types of variation, such as the maximum number of ossification centers observed in the sternum and particularly the development of the manubrium. He also fails to mention

premature sternal fusion which in this study was observed to occur at verly ages in individuals considered to be normal by growth standards. In his mauscript he depicts the manubrium as a single center of ossification in all of his 16 "regular" patterns of ossification, with no mention of the manubrium developing from two or as many as six centers.

If there is to be any disagreement stemming from the results of this study, they are with many of these basic anatomy texts which are used in academic institutions today. These texts fail to mention the variability of ossification patterns in the human sternum and have one believing that there are only one or two ways in which the sternum ossifies. Other misinformation concerns the fusion of the sternal body to the manubrium and ossification of the xiphoid. This dissertation research went a step further than previous studies in describing various sternal anomalies. For example xiphoid ossification was observed to occur as early as 7 years of age and premature fusion of the sternal body to the manubrium as early as 5 months of age.

Statistical analysis in this study showed that the total number of ossification centers in the sternum could possibly be used as a method for determing the age of a fetus or infant. This method would however not be as feasible as other established methods which inturn have been shown to be more accurate.

The most significant finding of this study was the observation of sexual dimorphism in relation to the total number of ossification centers in the sternum. Application of this information is

precluded as a method of sexing a fetus or infant, since other methods could used with greater accuracy. The observation of sexual dimorphisim has provided new questions as to cause. One might speculate that this dimorphisim is related to the final dimensions of the adult sternum which has been shown to be larger in male sthan in females. On the other hand the increased number of ossification centers in the developing male sternum might just be a function of early hormonal growth patterns.

Continued research on these data may answer the question of sexual dimorphism of the developing sternum in relation to the adult form. This problem will mainly be a methodological one in which methods for measuring the developing centers of ossification in the autopsy population as well as longitudinal study of living populations should be devised.

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APPENDIX

FIGURES

1. The Early Development of the Human Sternum
2. Faxitron Unit Used in this Study

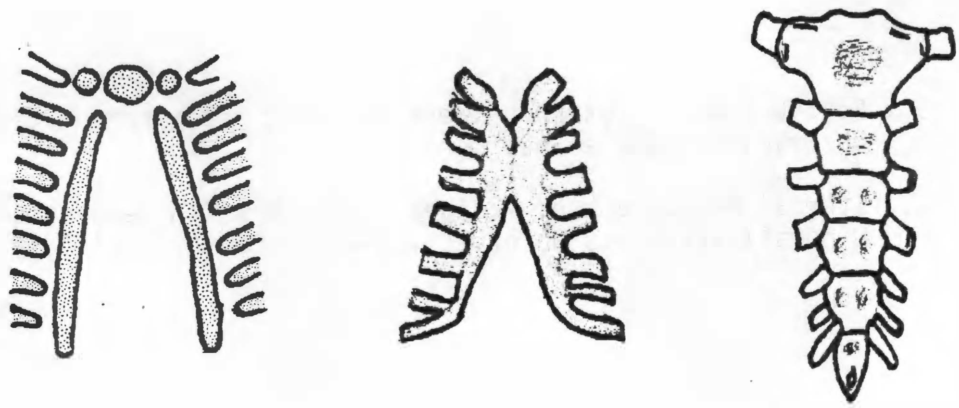


Figure 1

Figure 2

3. Four Grades of Fusion between Adjacent Ossification Centers as Observed in Sample Specimen

4. Sternal Radiograph of Youngest Case in which Demonstrable Mineralization was Observed (18 Weeks Gestational Age)

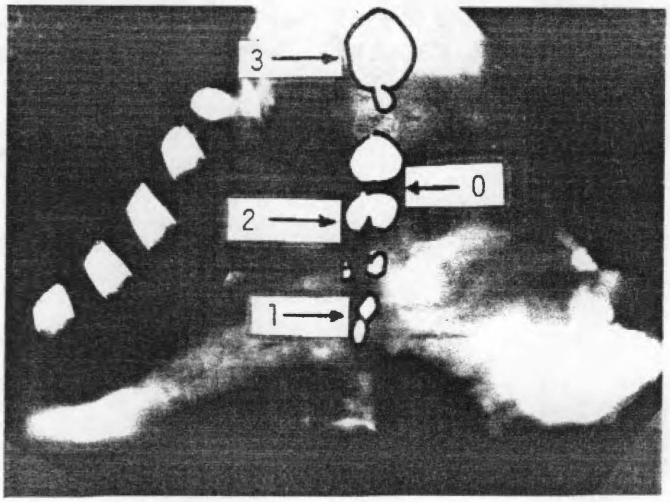


Figure 3

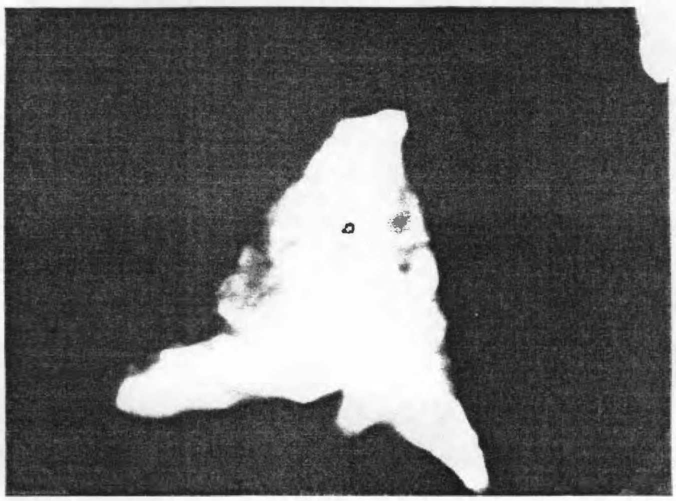


Figure 4

5. Sternal Radiograph of a 42 Week Fetus with a Total of 13 Ossification Centers in the Sternum

6. Sternal Radiograph of a Fetus having Ossification Centers in the Sternabra with no Manubrial Center of Ossification # 1

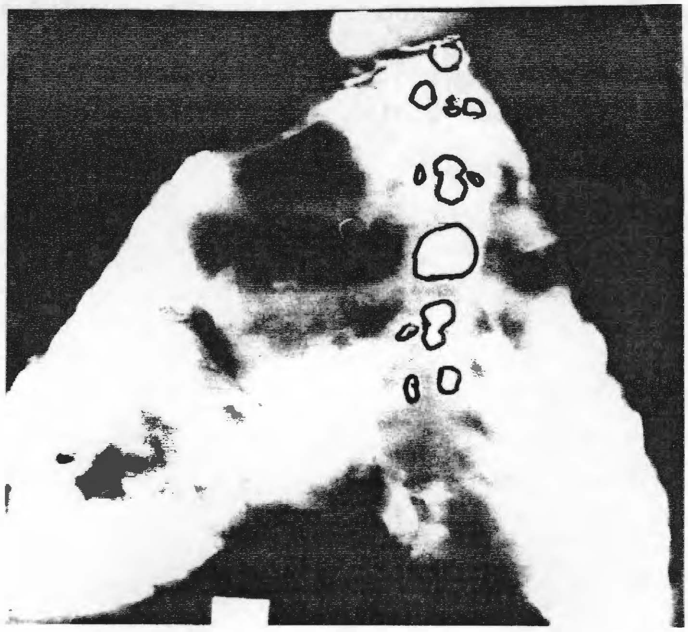


Figure 5

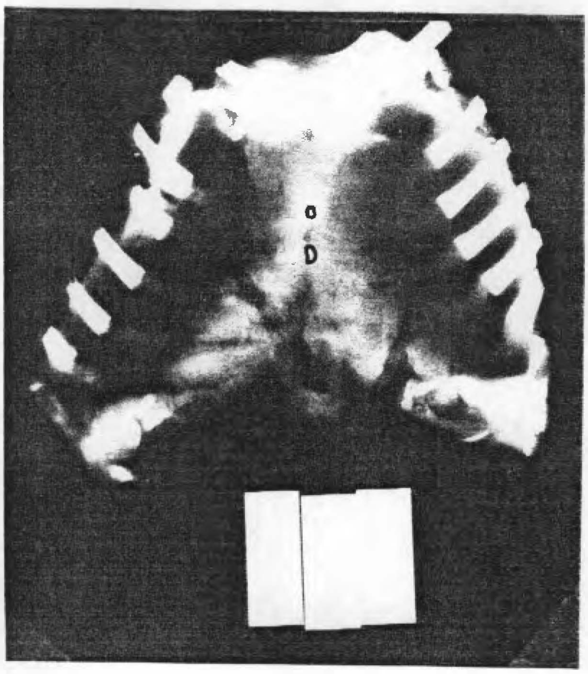


Figure 6

7. Sternal Radiograph of a Fetus having Ossification Centers in the Sternabra with no Manubrial Center of Ossification # 2

8. Sternal Radiograph Showing Grade 1 Fusion between the Manubrial Ossification Center and Sternabra 1

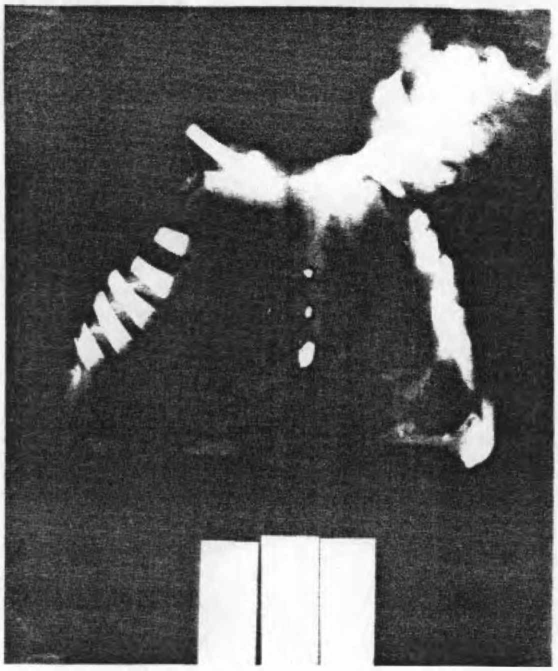


Figure 7

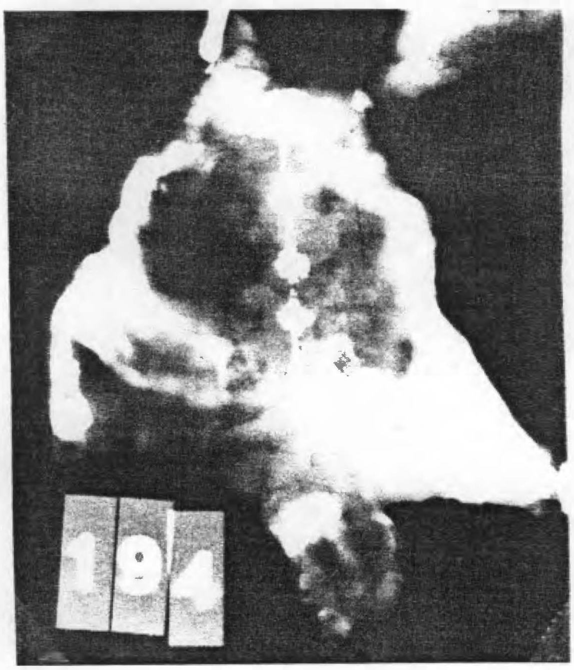


Figure 8

9. Sternal Radiograph Showing Sternal Development in a 37 Week Old Fetus

10. Sternal Ossification as Viewed in Dried Sternum of Newborn # 1

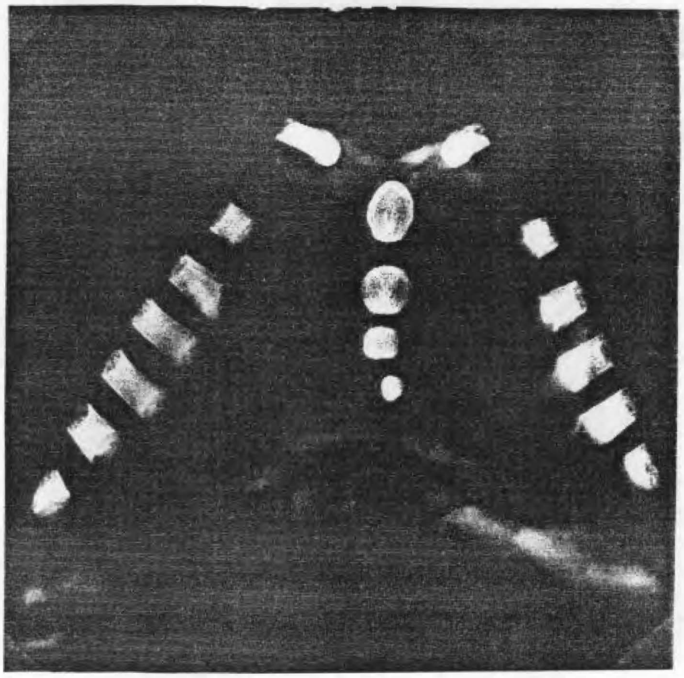


Figure 9

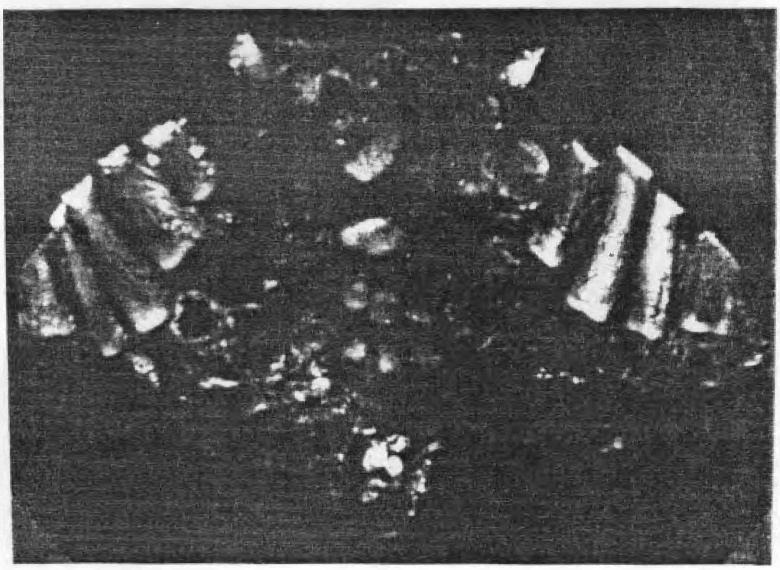
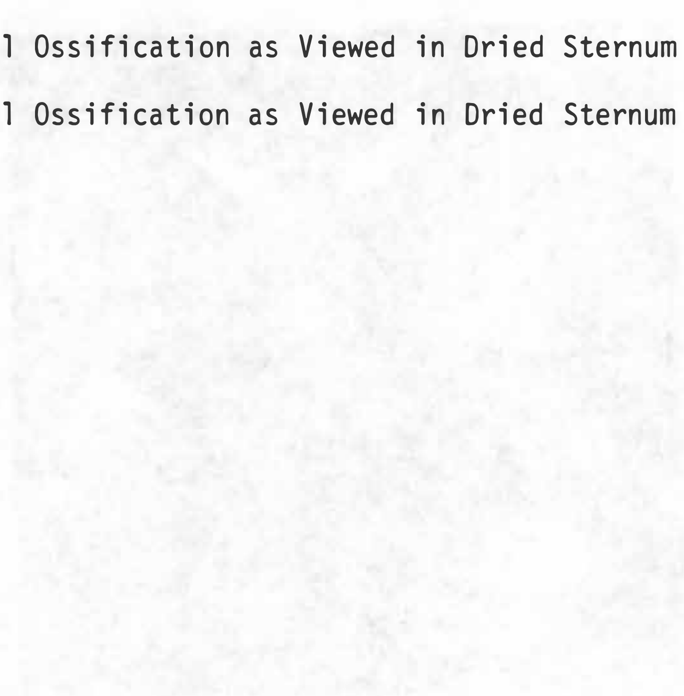
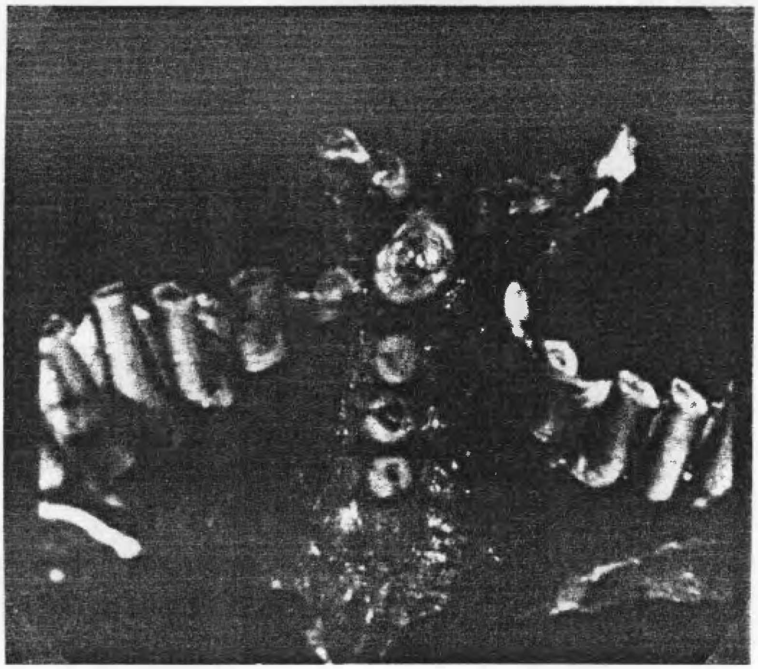


Figure 10

11. Sternal Ossification as Viewed in Dried Sternum of Newborn # 2

12. Sternal Ossification as Viewed in Dried Sternum of Newborn # 3





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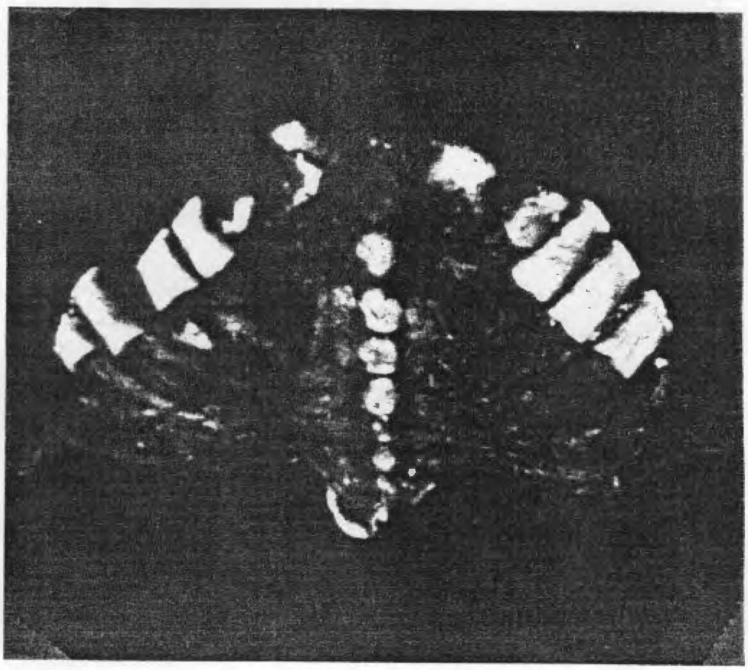
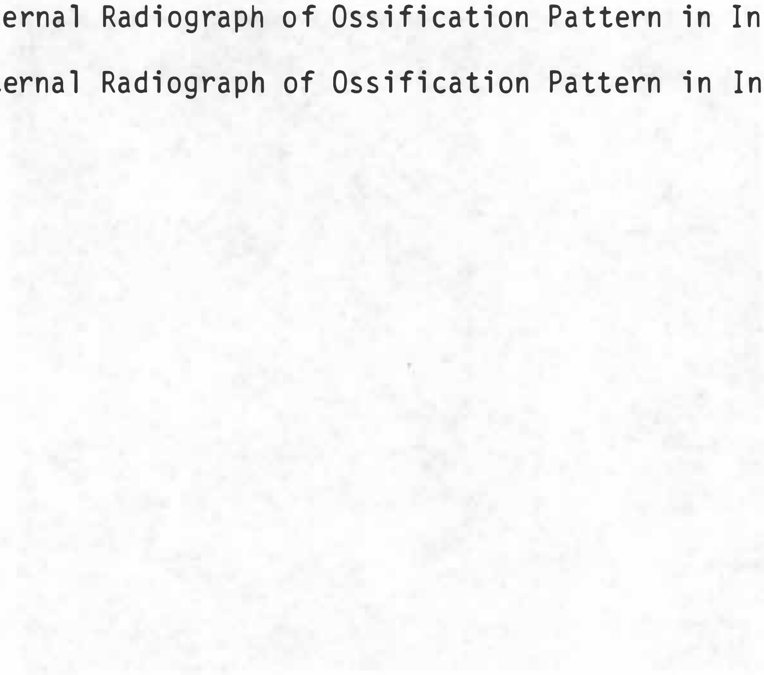
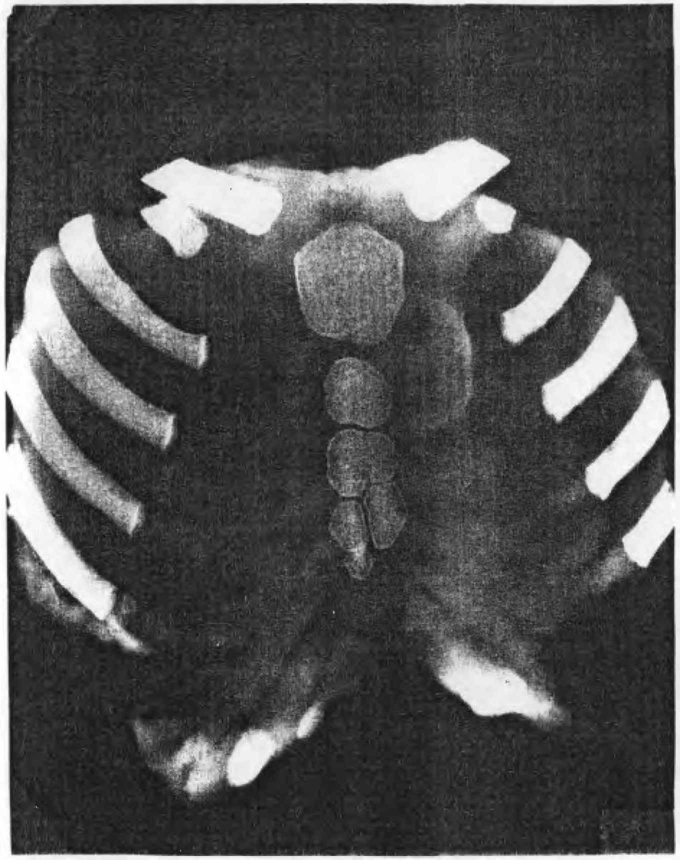


Figure 12

13. Sternal Radiograph of Ossification Pattern in Infant # 1

14. Sternal Radiograph of Ossification Pattern in Infant # 2





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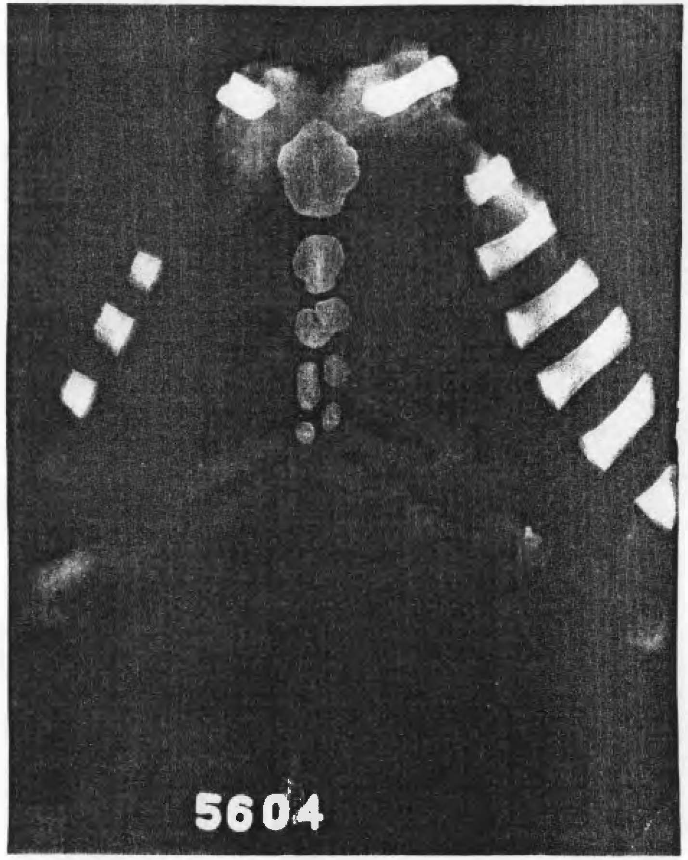
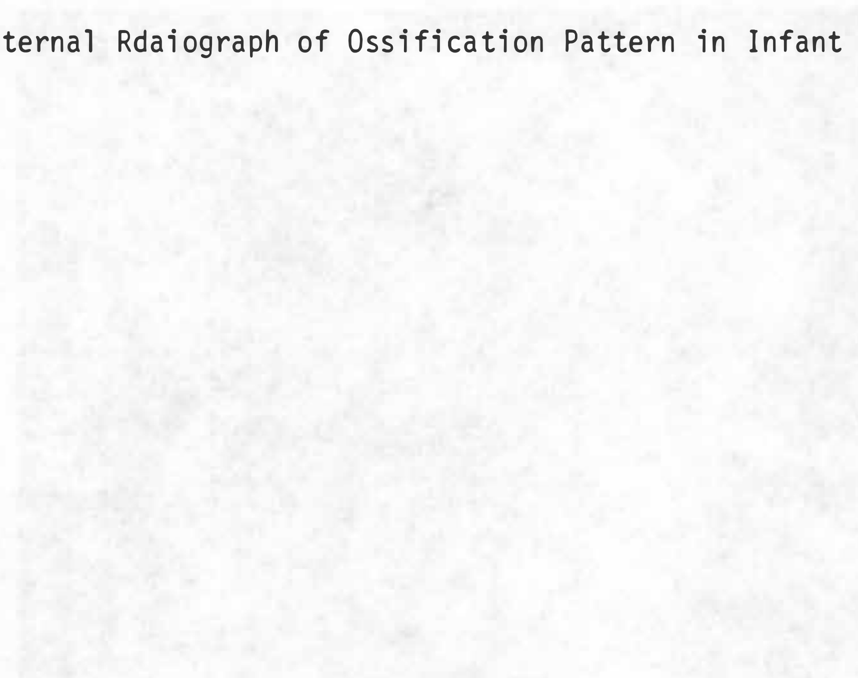
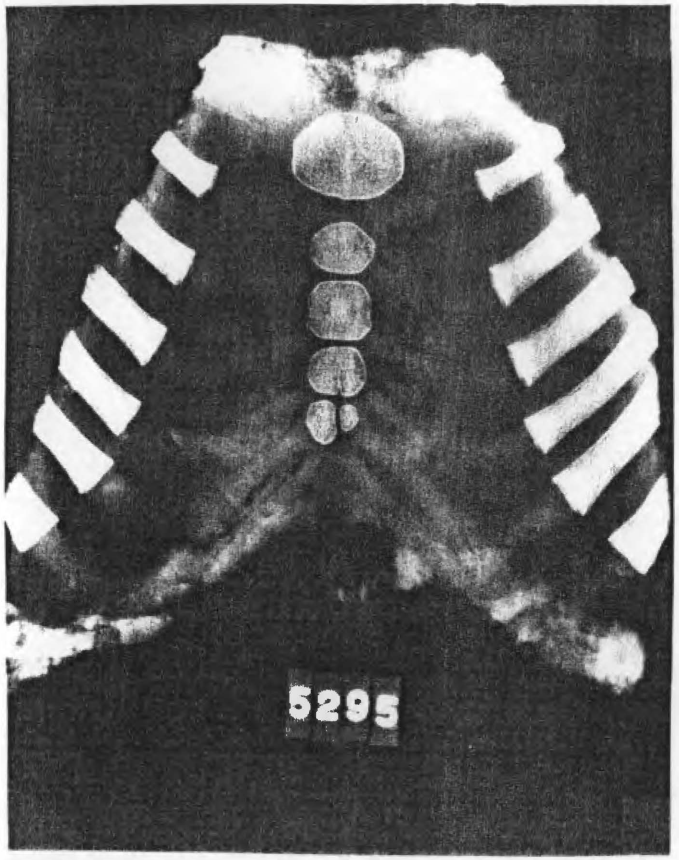


Figure 14

15. Sternal Radiograph of Ossification Pattern in Infant # 3

16. Sternal Rdaiograph of Ossification Pattern in Infant # 4





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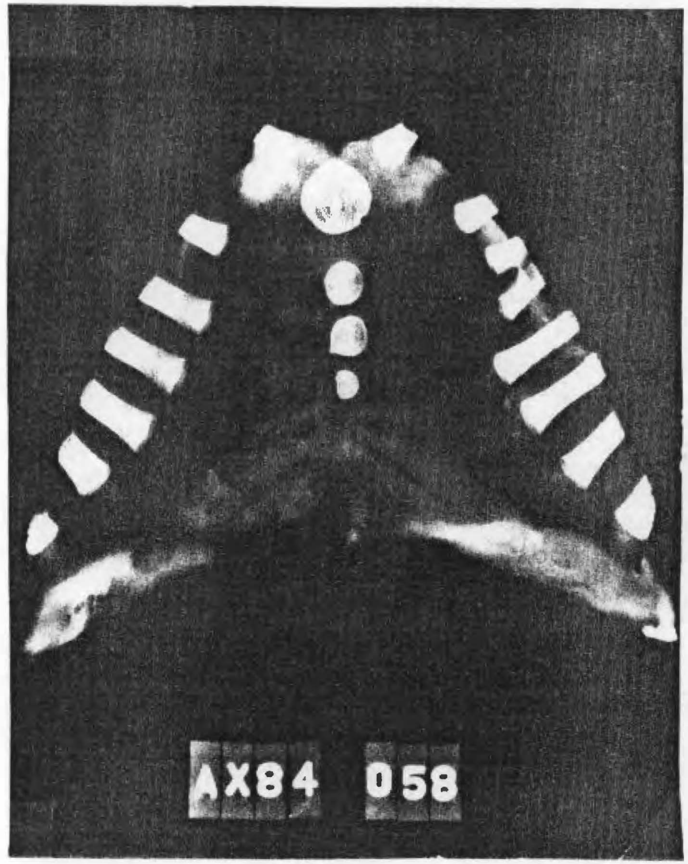
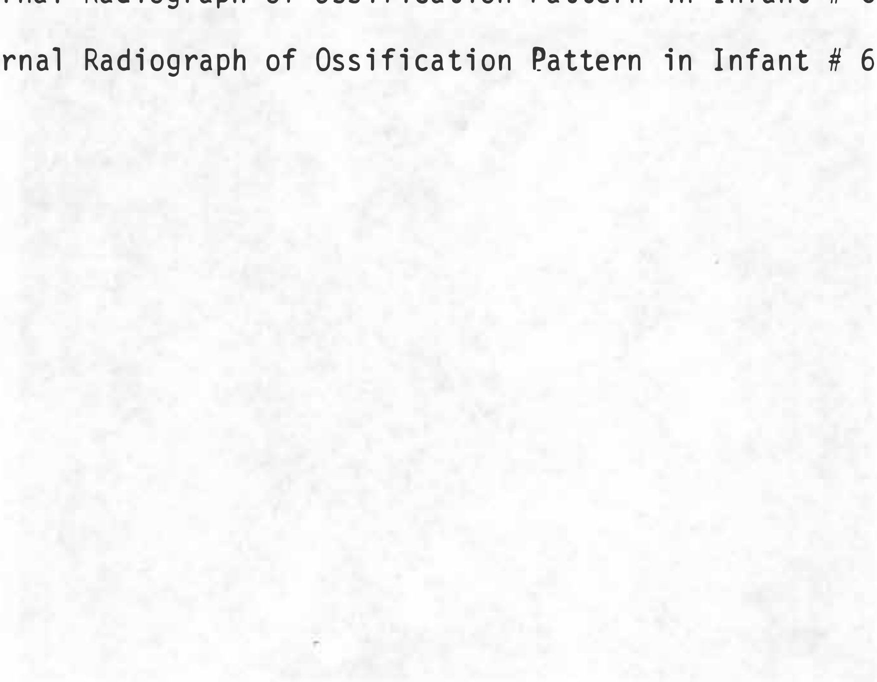
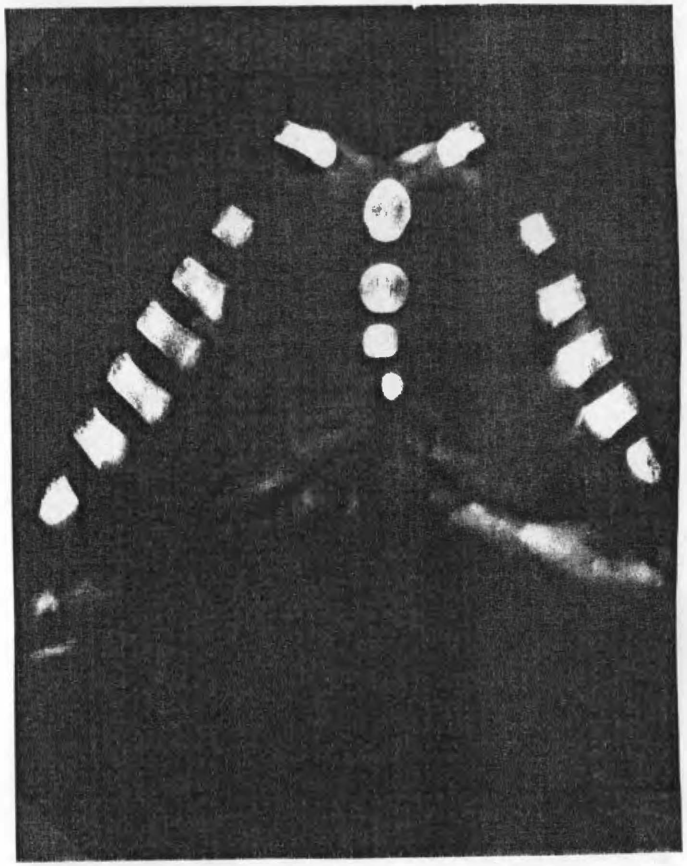


Figure 16

17. Sternal Radiograph of Ossification Pattern in Infant # 5

18. Sternal Radiograph of Ossification Pattern in Infant # 6





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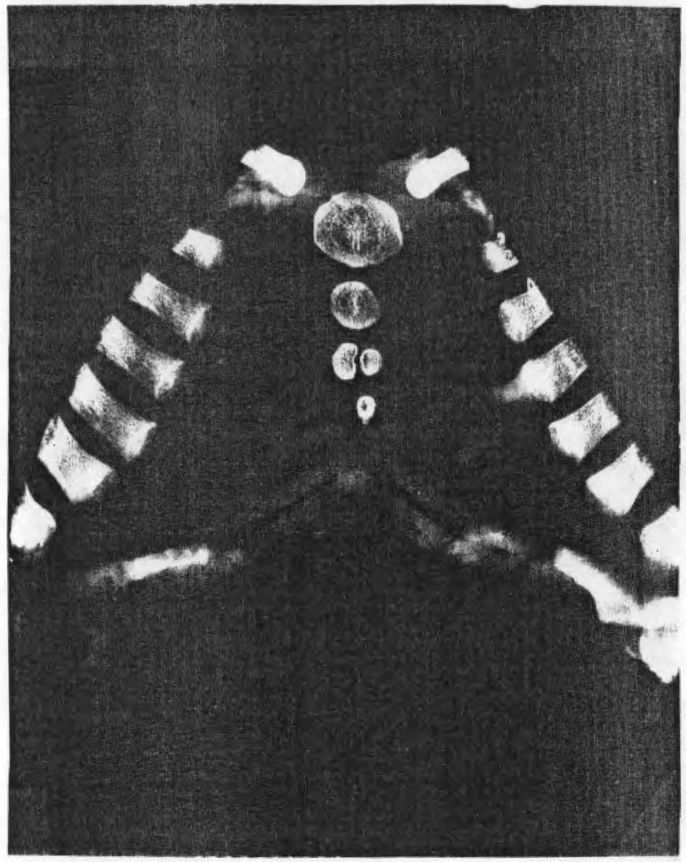
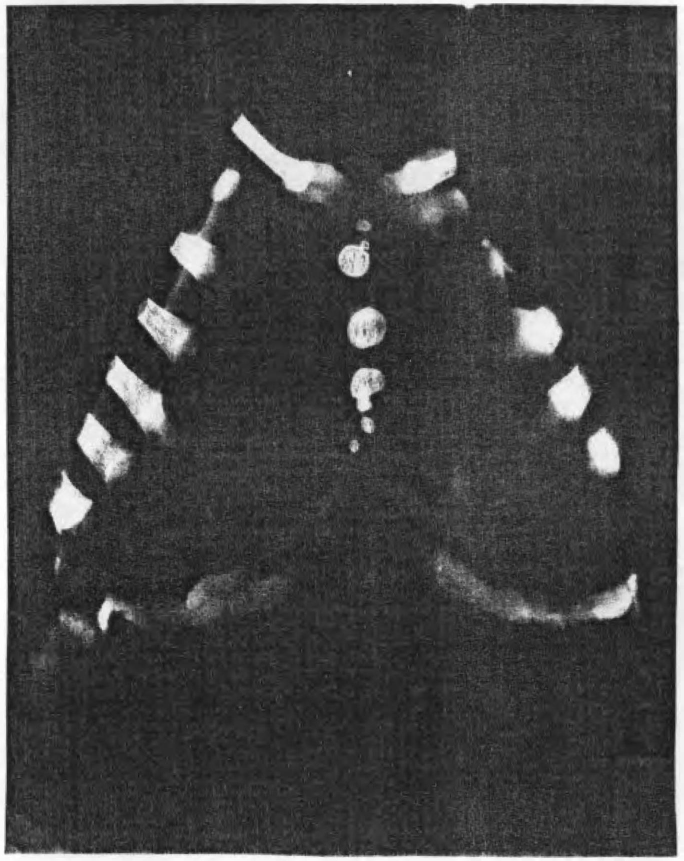


Figure 18

19. Sternal Radiograph of Ossification Pattern in Infant # 7

20. Sternal Radiograph of Ossification Pattern in Infant # 8



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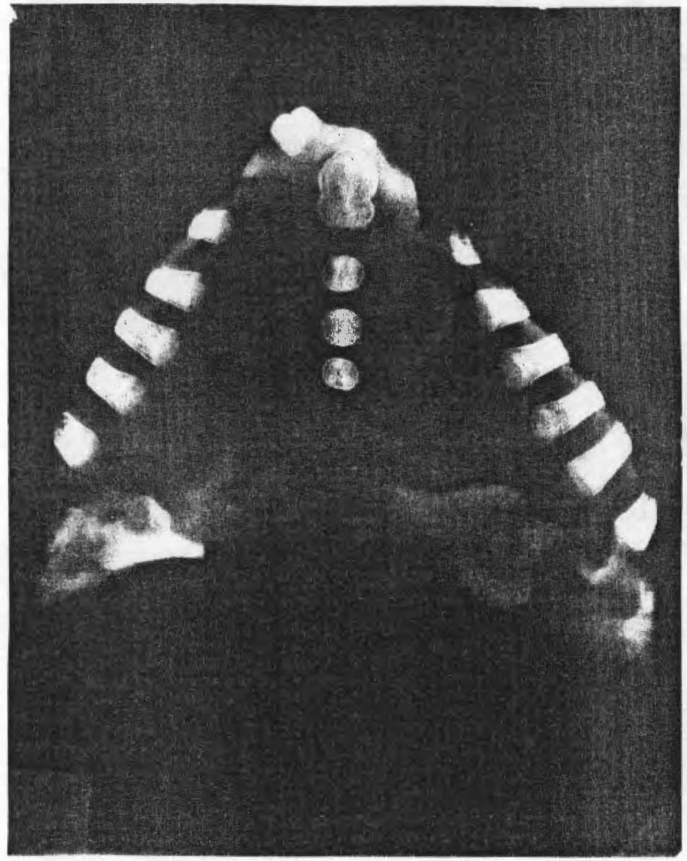
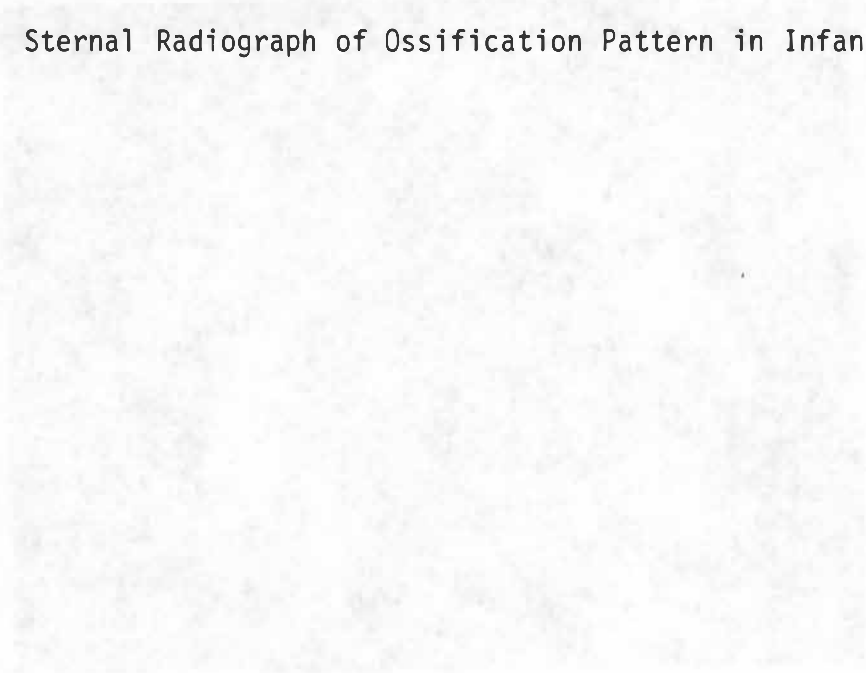


Figure 20

21. Sternal Radiograph of Ossification Pattern in Infant # 9

22. Sternal Radiograph of Ossification Pattern in Infant # 10



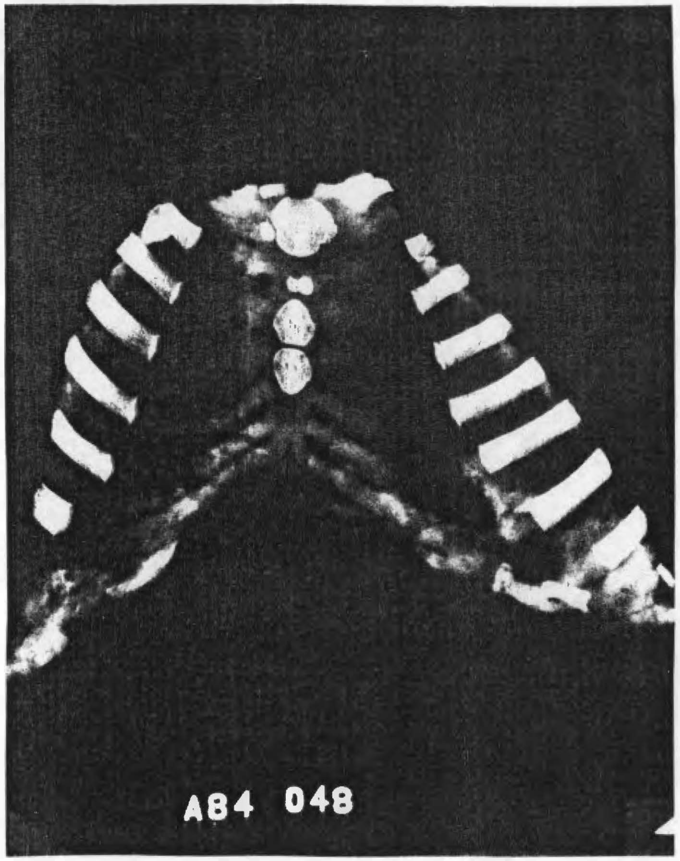


Figure 21

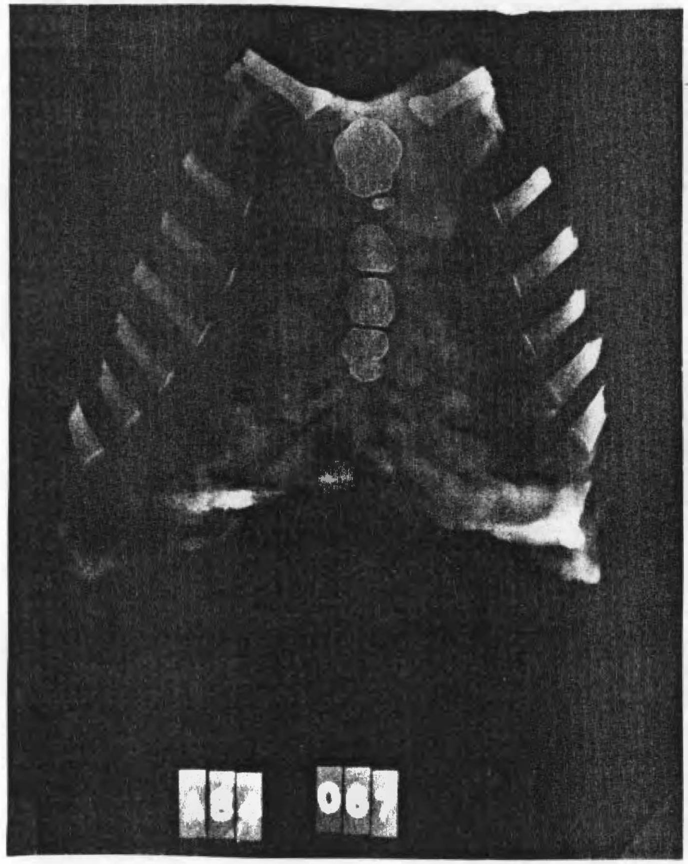
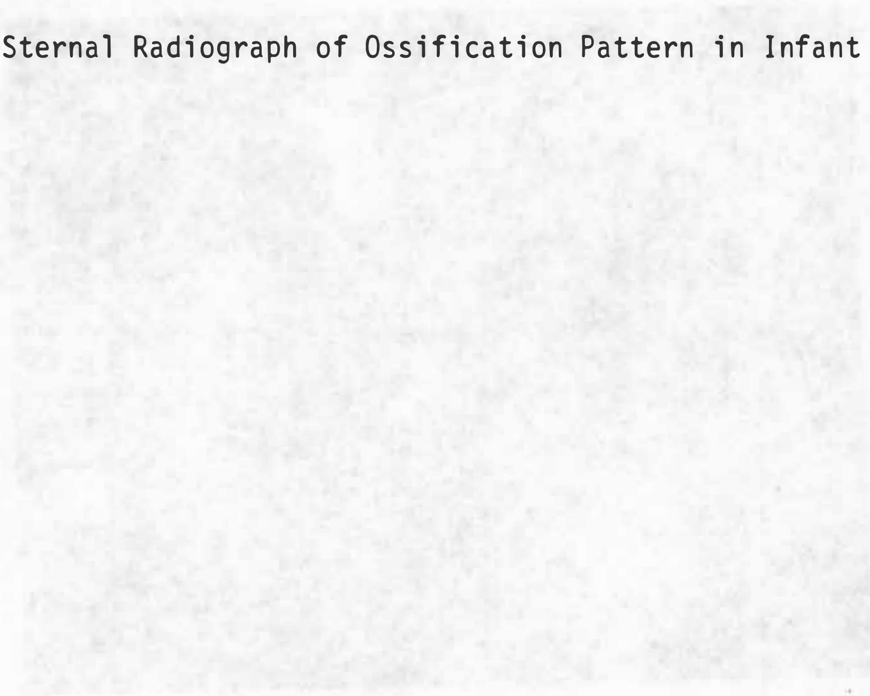
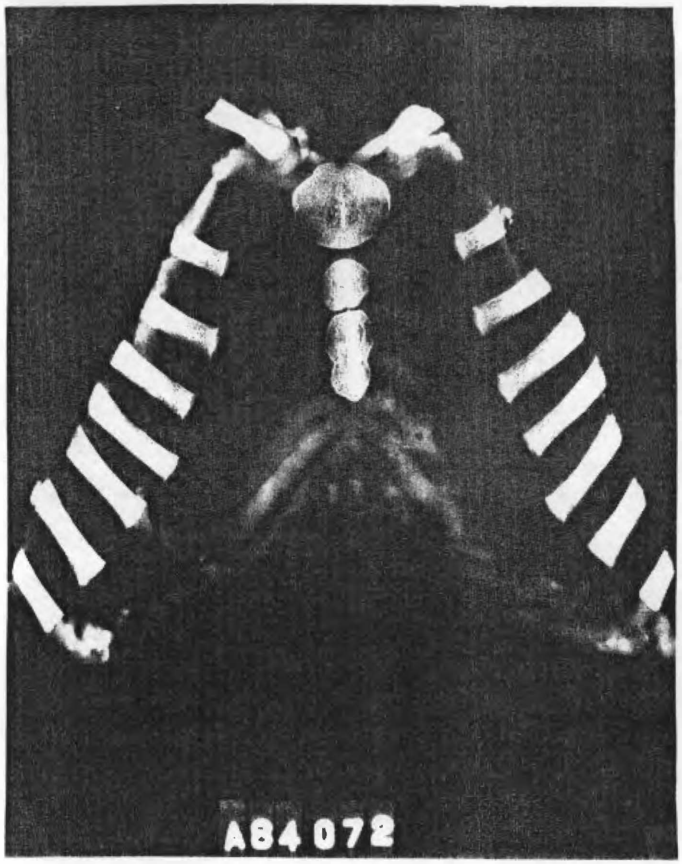


Figure 22

23. Sternal Radiograph of Ossification Pattern in Infant # 11

24. Sternal Radiograph of Ossification Pattern in Infant # 12





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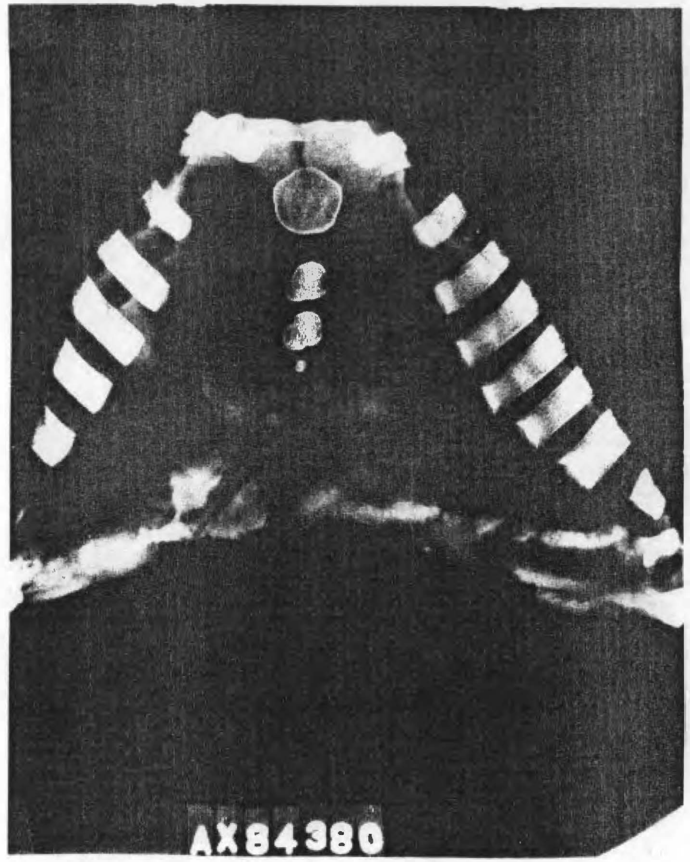
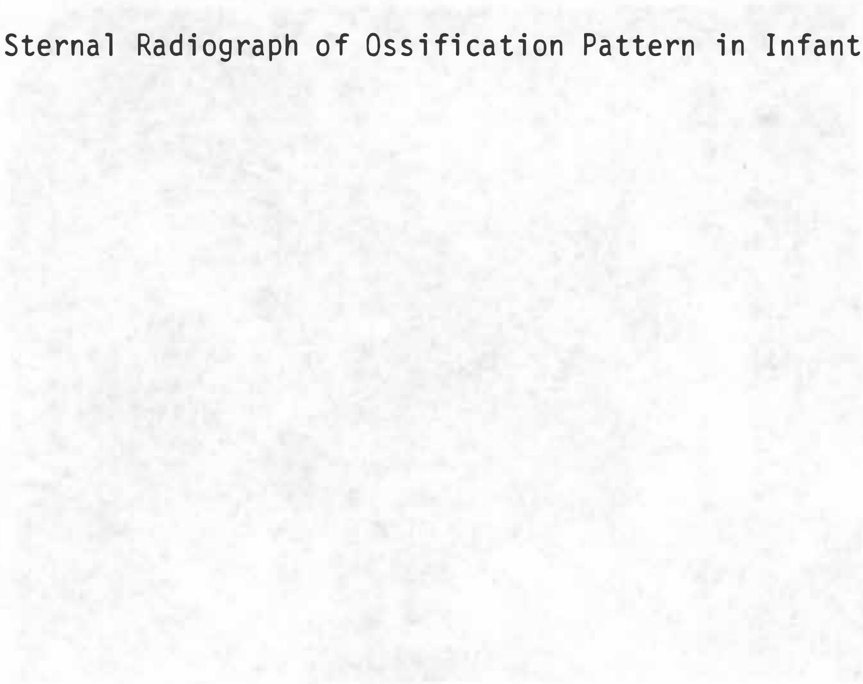
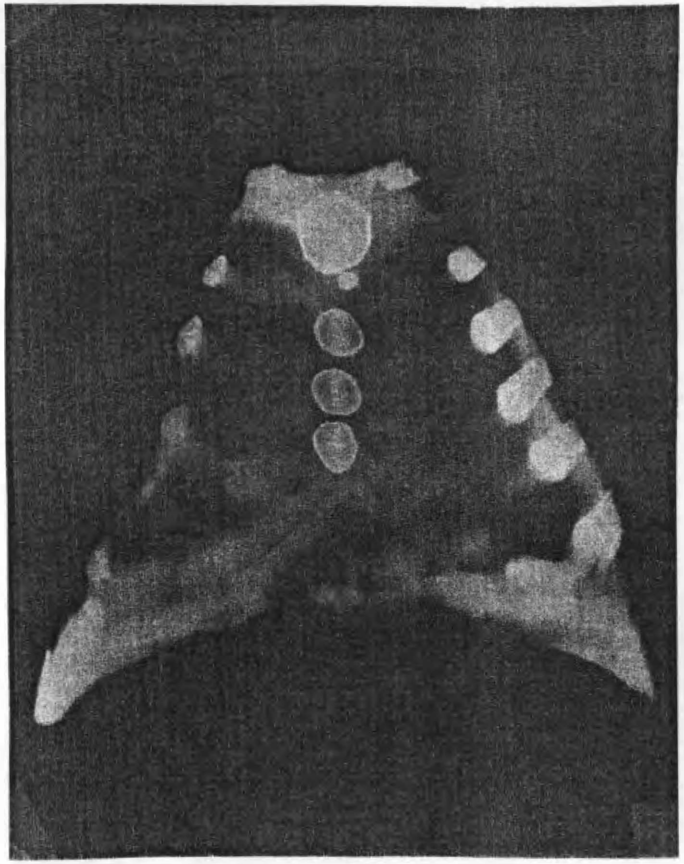


Figure 24

25. Sternal Radiograph of Ossification Pattern in Infant # 13

26. Sternal Radiograph of Ossification Pattern in Infant # 14





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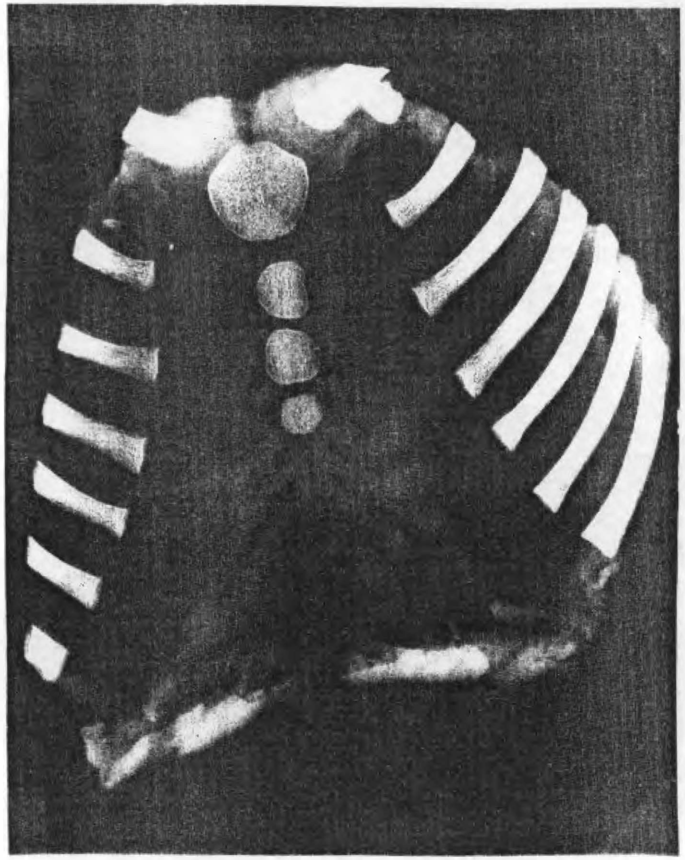
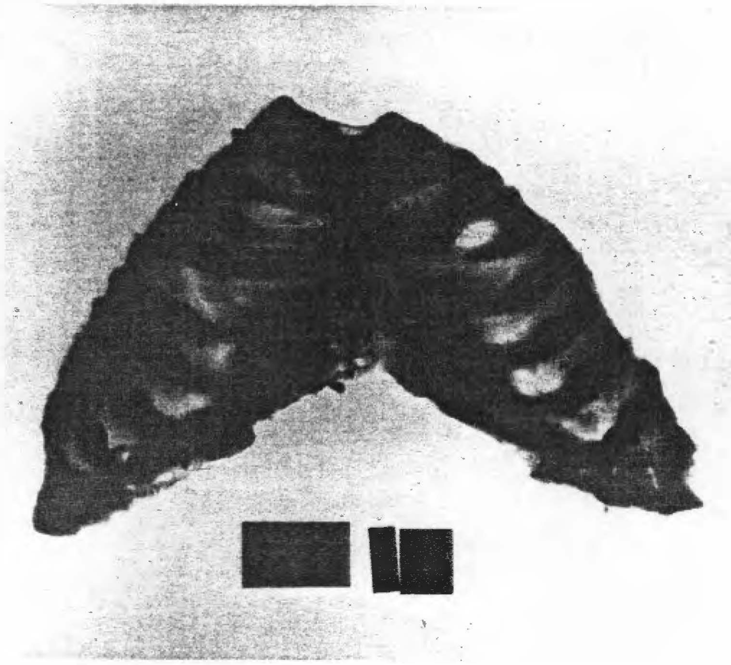


Figure 26

27. Sternal Radiograph Showing Premature Fusion in Infant # 1

28. Sternal Radiograph Showing Premature Fusion in Infant # 2



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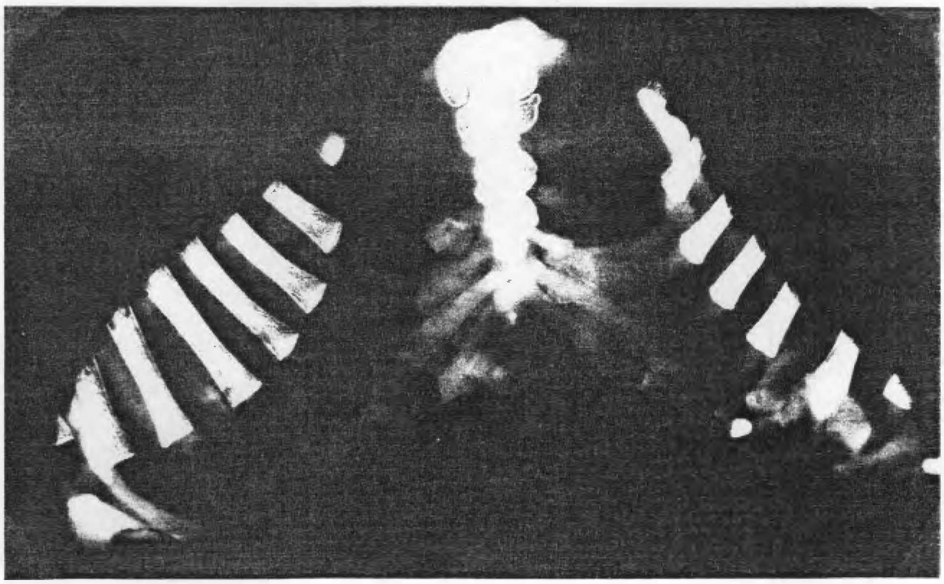
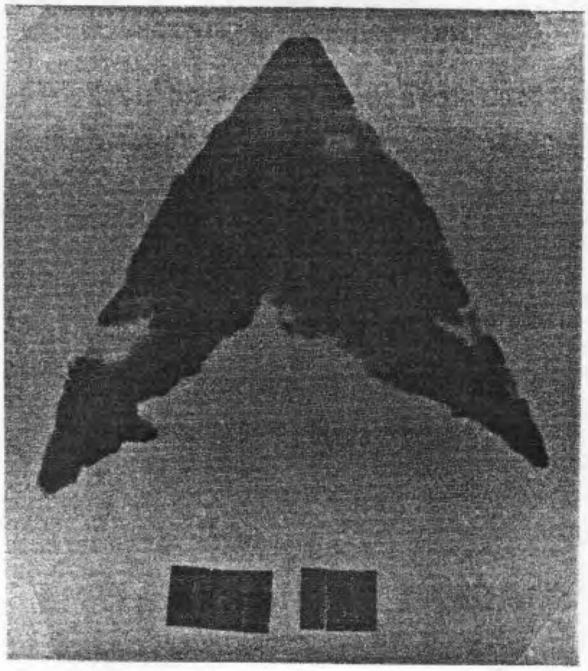


Figure 28

29. Sternal Radiograph Showing Premature Fusion in Infant # 3

30. Cartilagenous Sternal Foramen as Observed in a 1 Month Old Black Female



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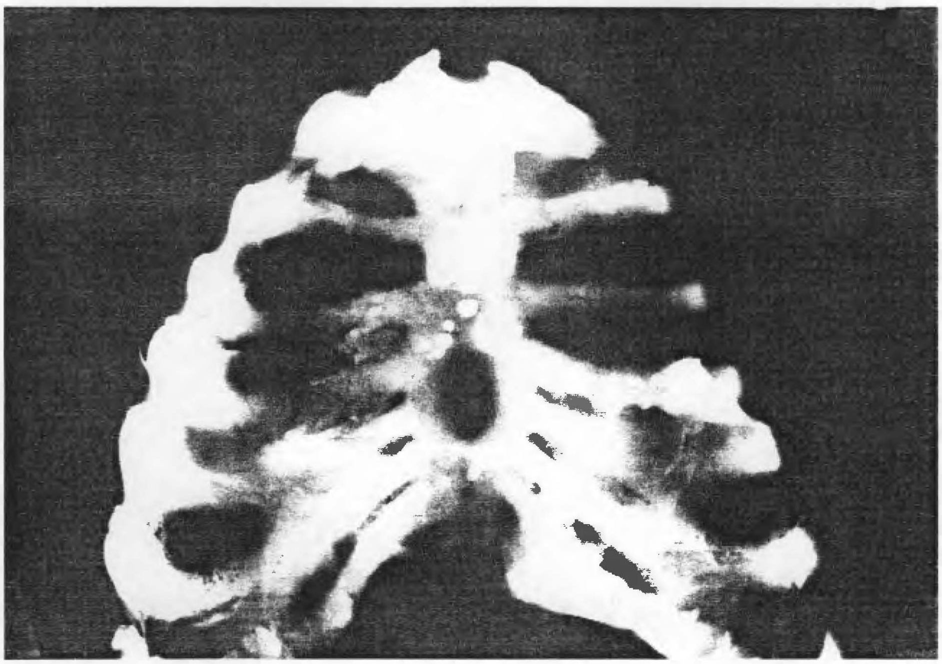
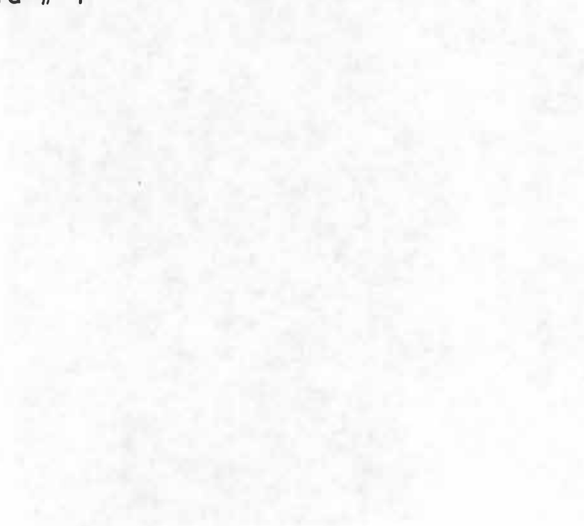
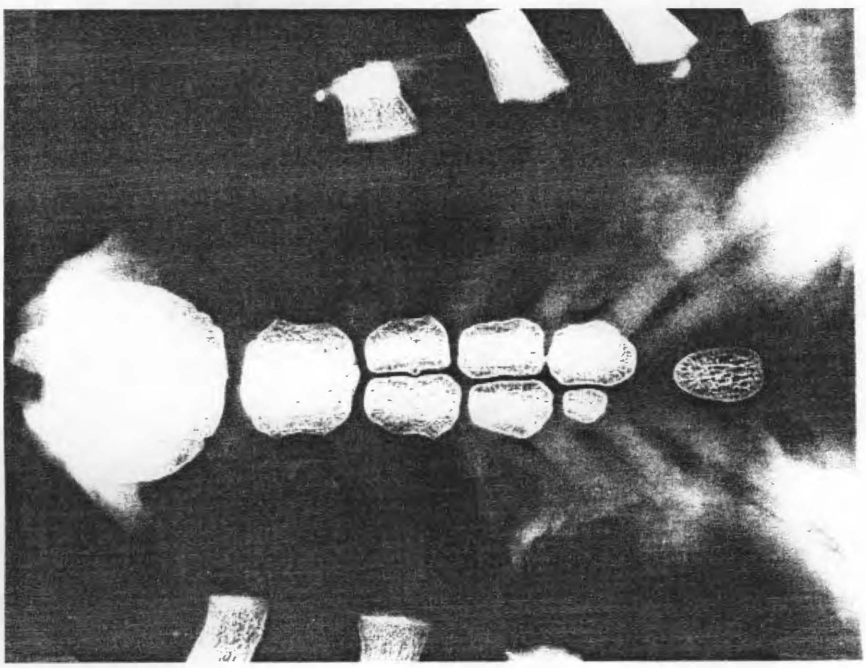


Figure 30

31. Sternal Radiograph of a 4 Year Old Black Female in Which 10 Ossification Centers were Observed

32. Sternal Radiograph Showing Pattern of Ossification in a Young Child # 1





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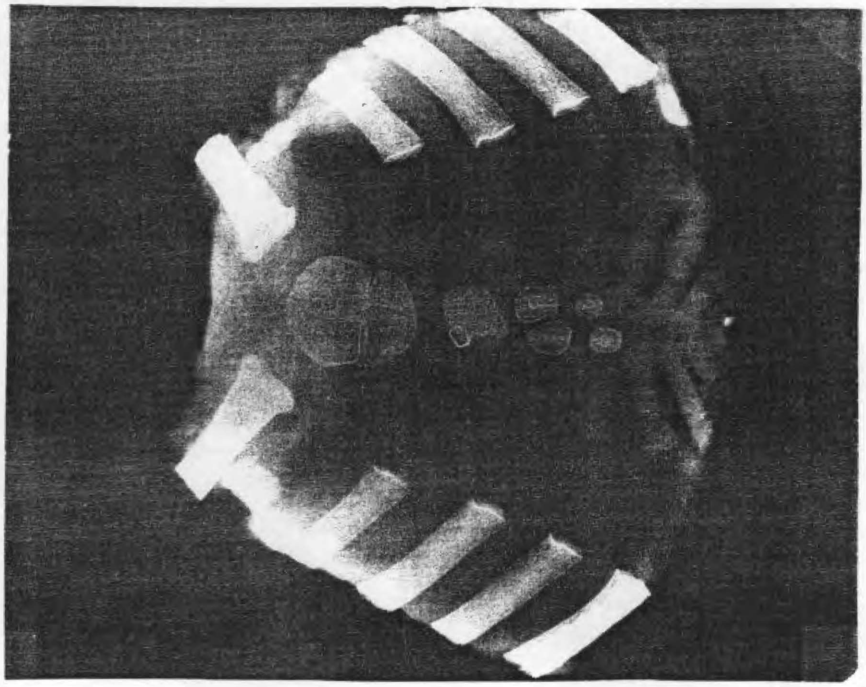
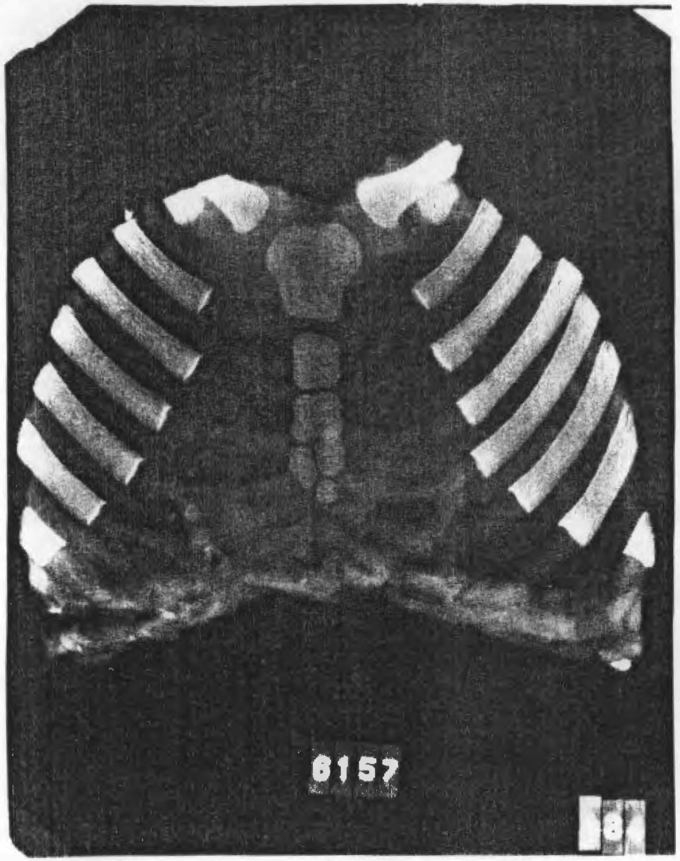


Figure 32

33. Sternal Radiograph Showing Pattern of Ossification in a Young Child # 2

34. Sternal Radiograph Showing Pattern of Ossification in a Young Child # 3



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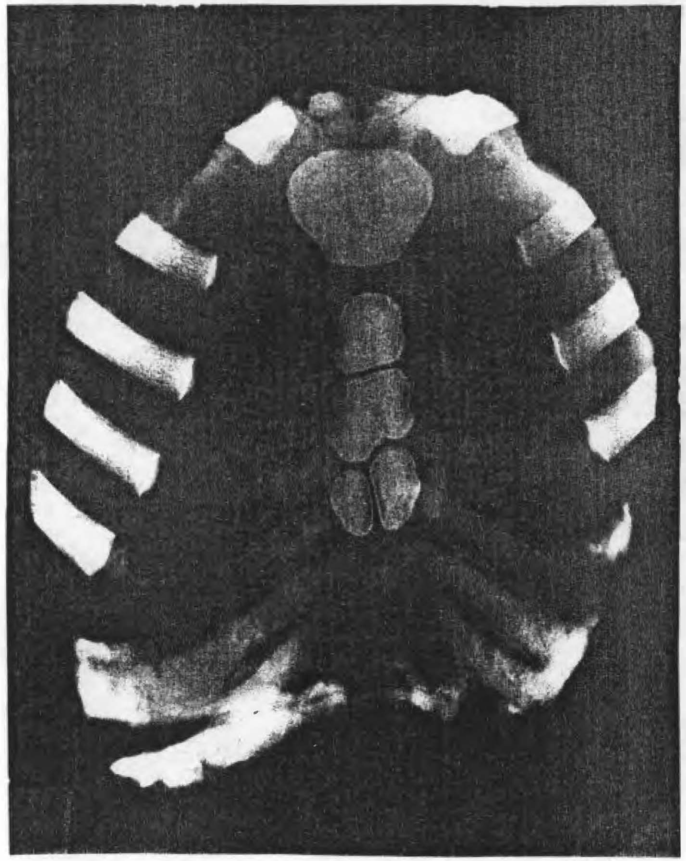


Figure 34

35. Sternal Radiograph of a 8 Year Old White Male in Which the Manubrium still Persists as Dual Centers of Ossification

36. Sternal Radiograph of a 7 Year Old White Male with Premature Ossification of the Xiphoid

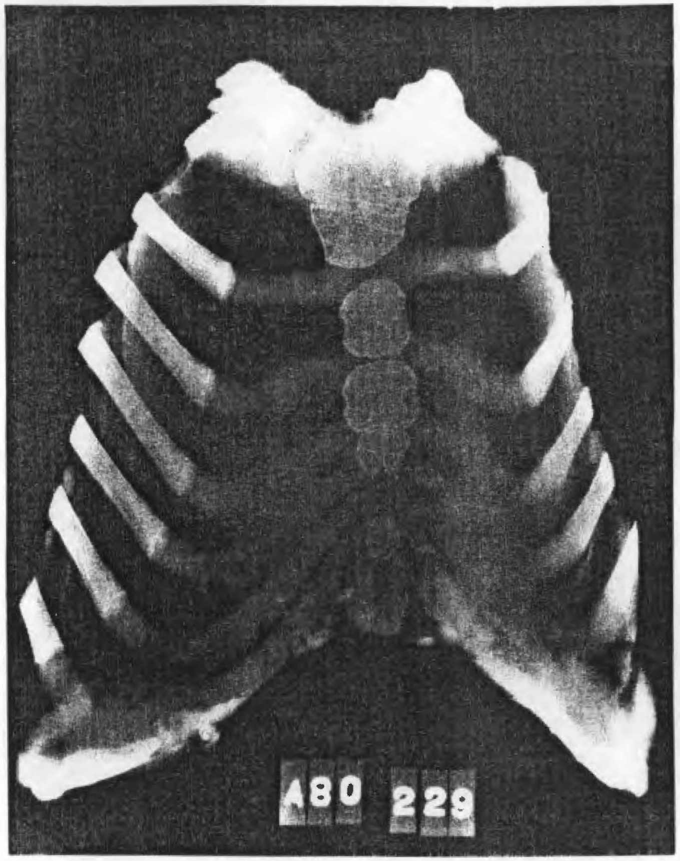


Figure 35

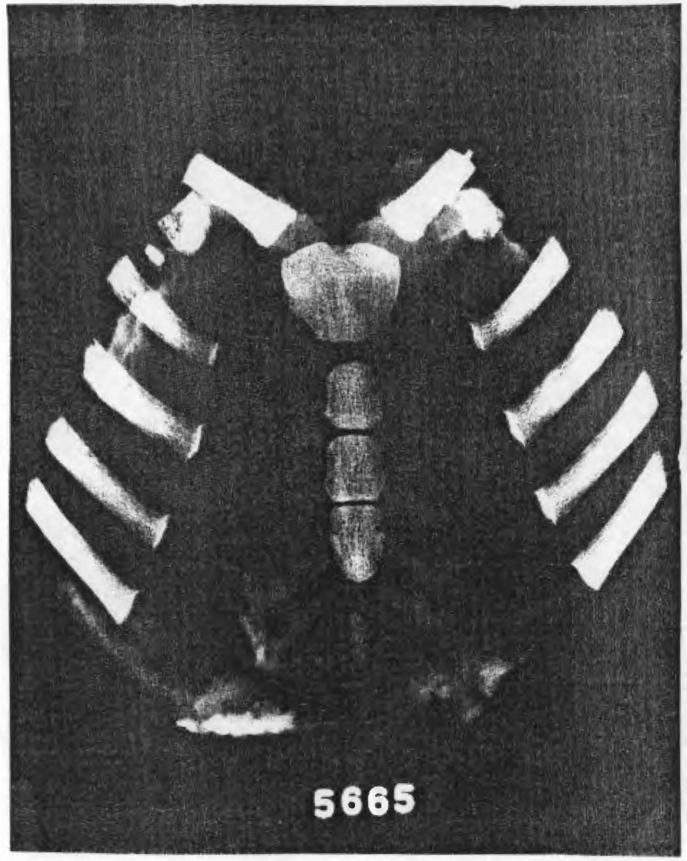


Figure 36

37. Sternal Radiograph of a 9 Year Old Latin Female with Premature Ossification of the Xiphoid

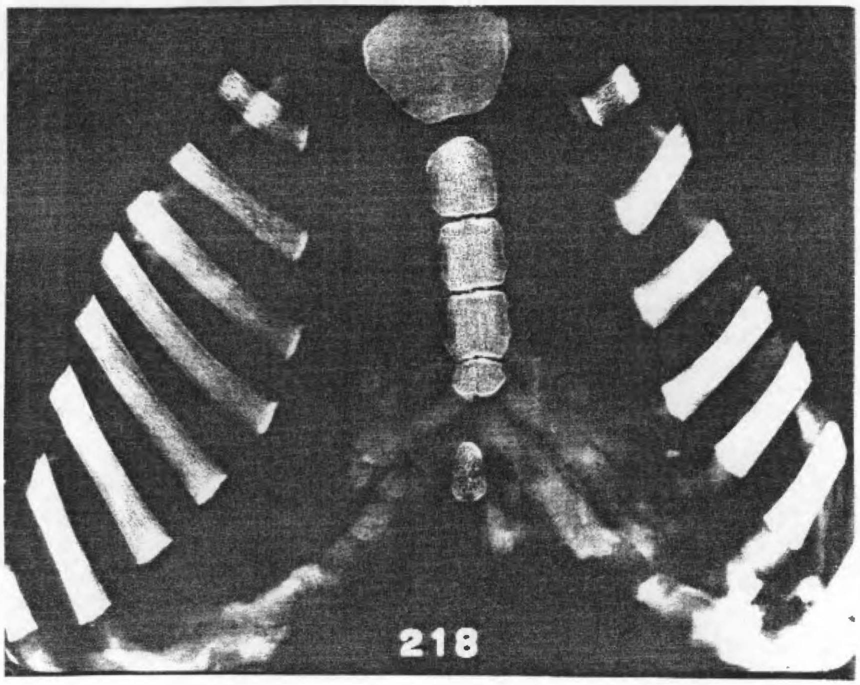


Figure 37

38. Sternal Radiograph of a 8 Year Old White Male in Which the Manubrium can still be Observed as Developing from Dual Centers of Ossification and there is the Presence of a Sternal Foramina

39. Sternal Radiograph of a 10 Year Old Latin Male with Early Ossification of the Xiphoid

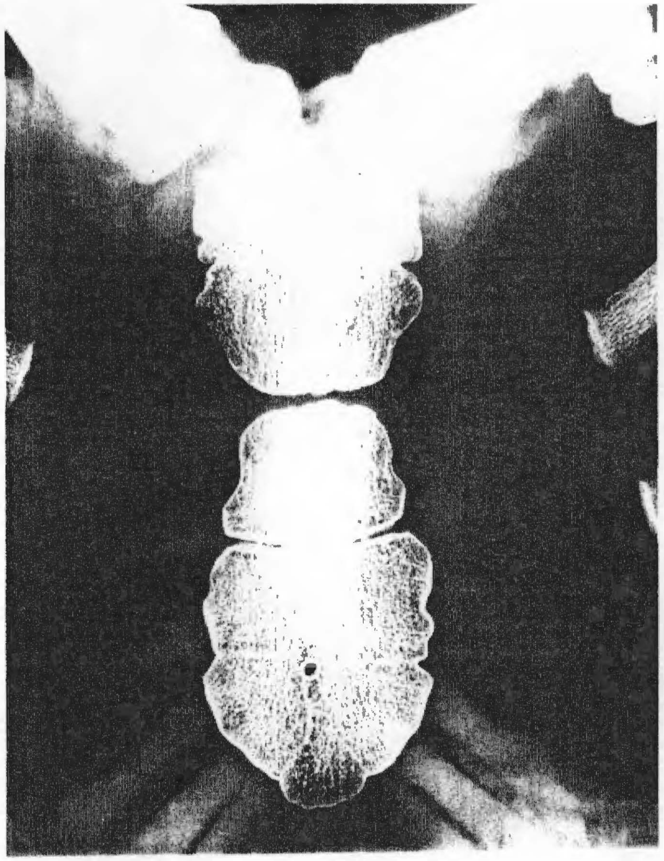


Figure 38

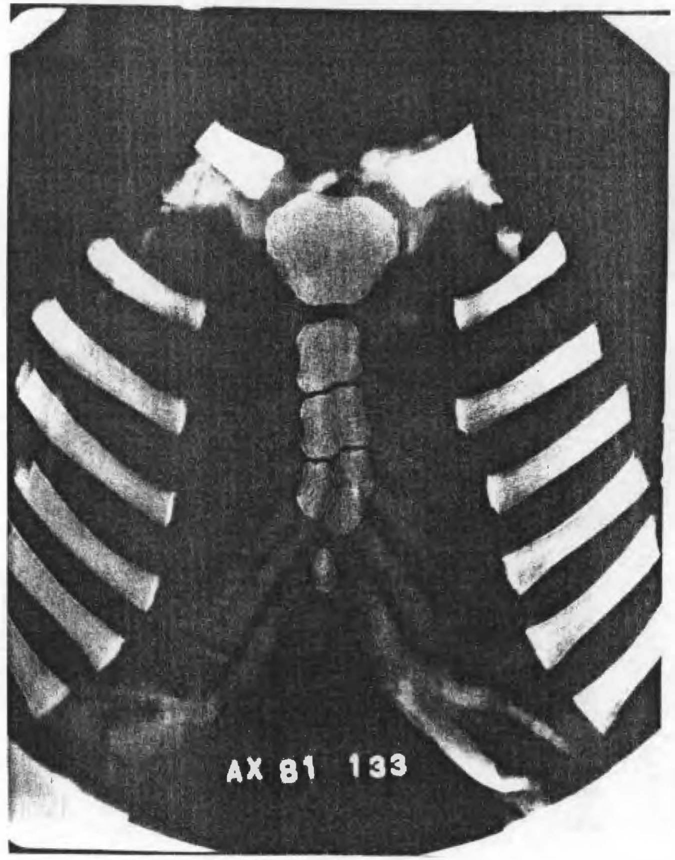


Figure 39

40. Sternal Radiograph of a 10 Year Old White Male with Early Ossification of the Xiphoid

41. Sternal Radiograph of a 11 Year Old White Female

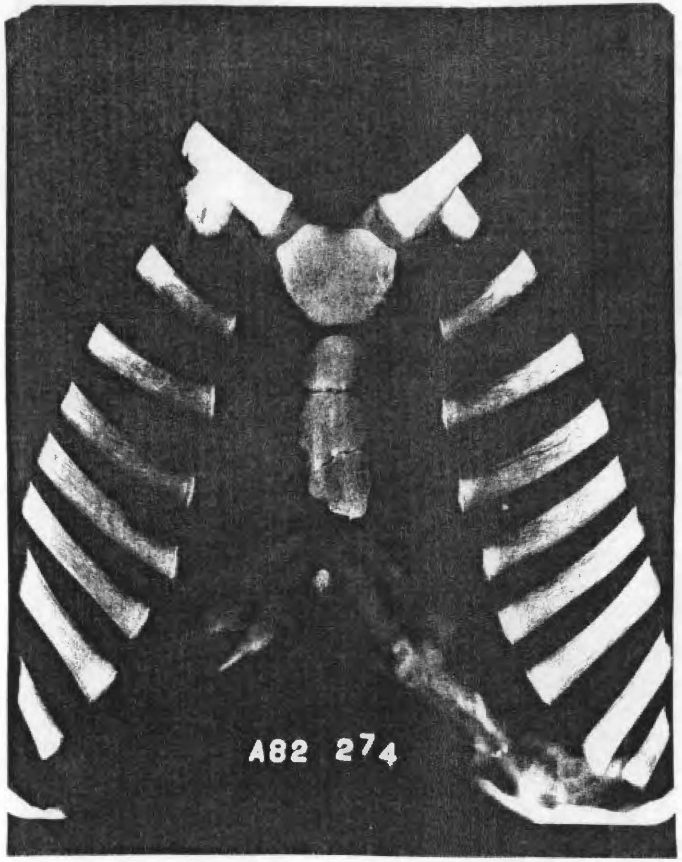


Figure 40

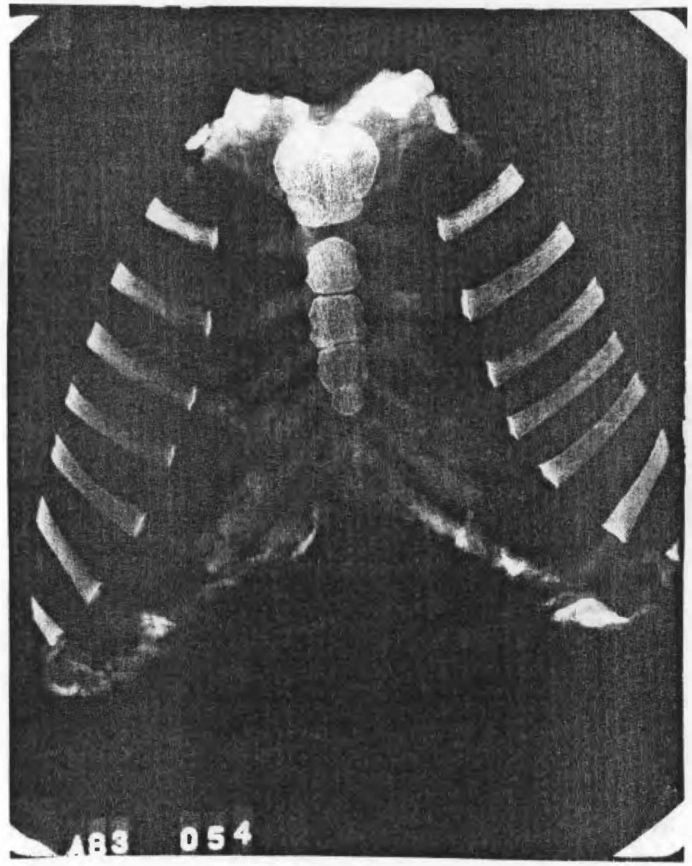
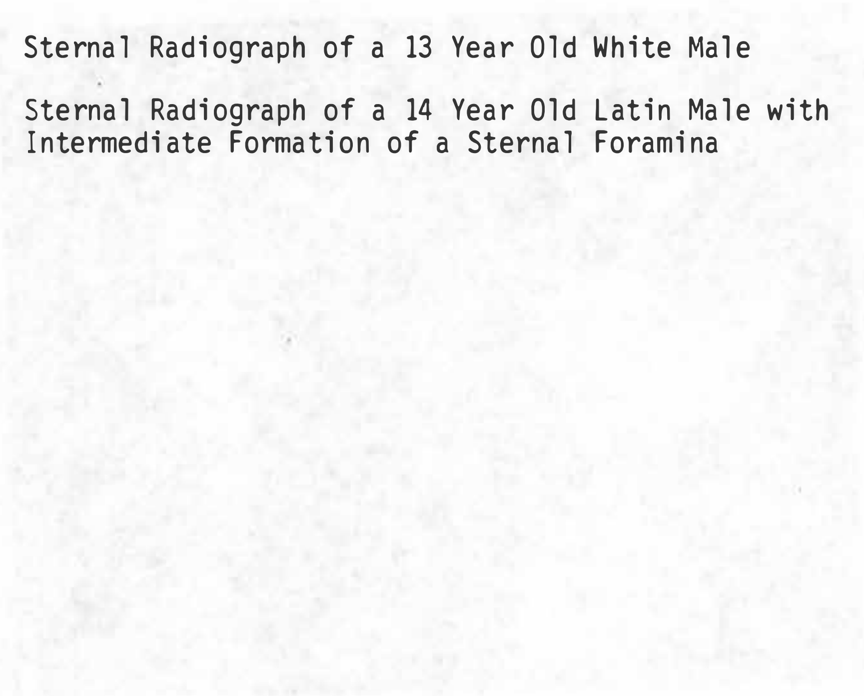
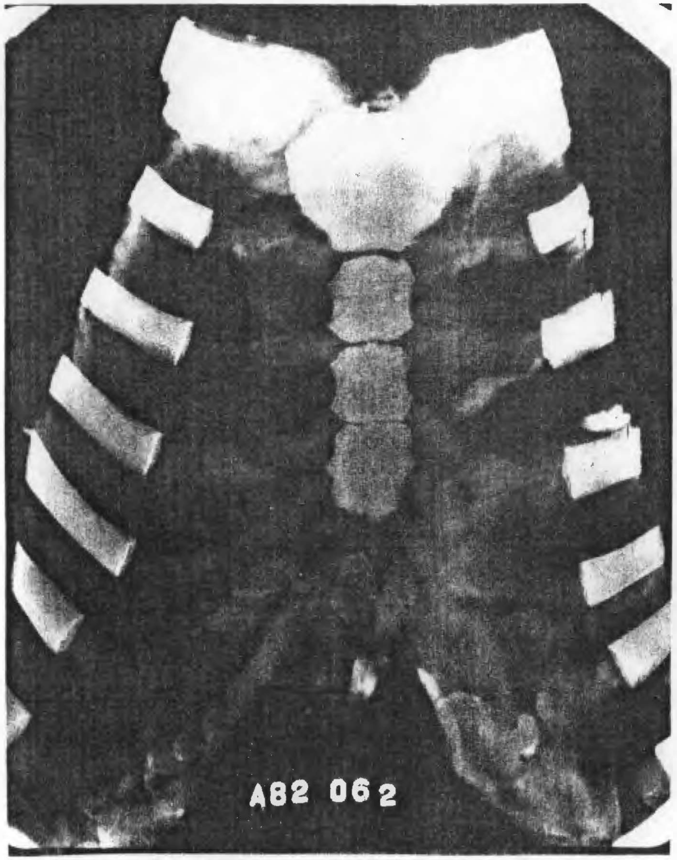


Figure 41

42. Sternal Radiograph of a 13 Year Old White Male

43. Sternal Radiograph of a 14 Year Old Latin Male with Intermediate Formation of a Sternal Foramina





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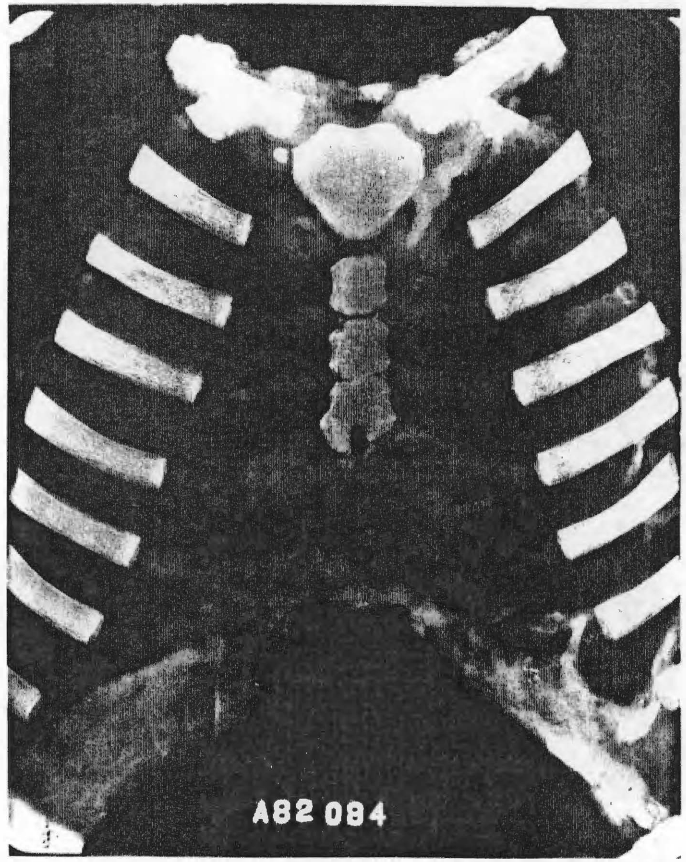
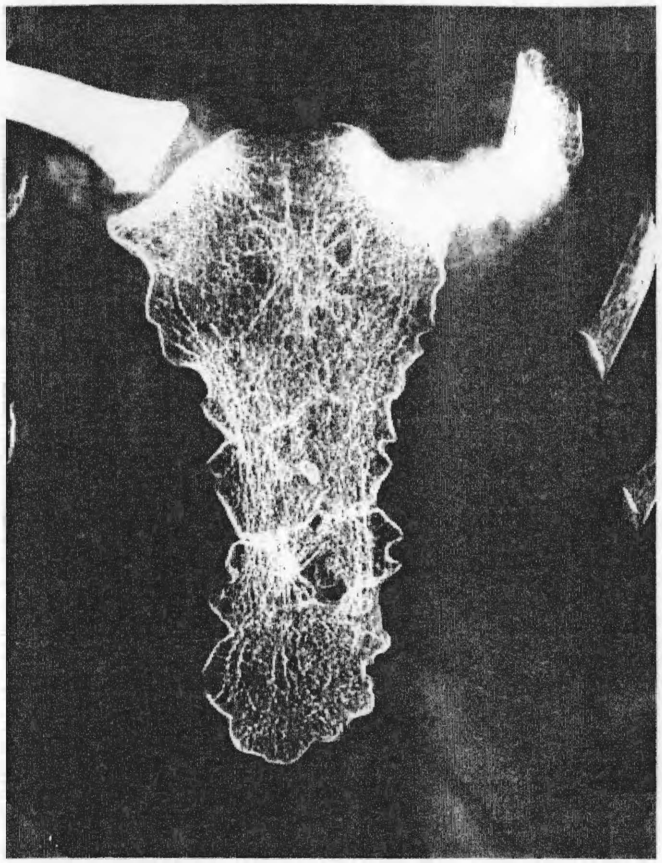


Figure 43

44. Sternal Radiograph of a 14 Year Old White Female Afflicted with Cerebral Palsy in which there is Premature Fusion of the Manubrium to the First Sternebra

45. Sternal Radiograph of a 15 Year Old Black Female Suffering from Prader-Willi's Syndrome, with the Absence of a Mesosternum



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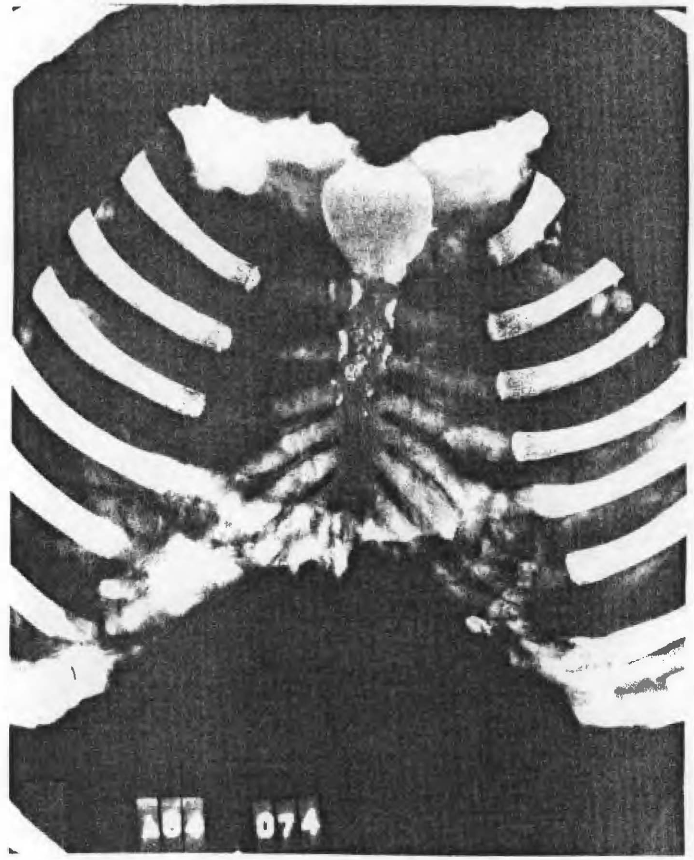
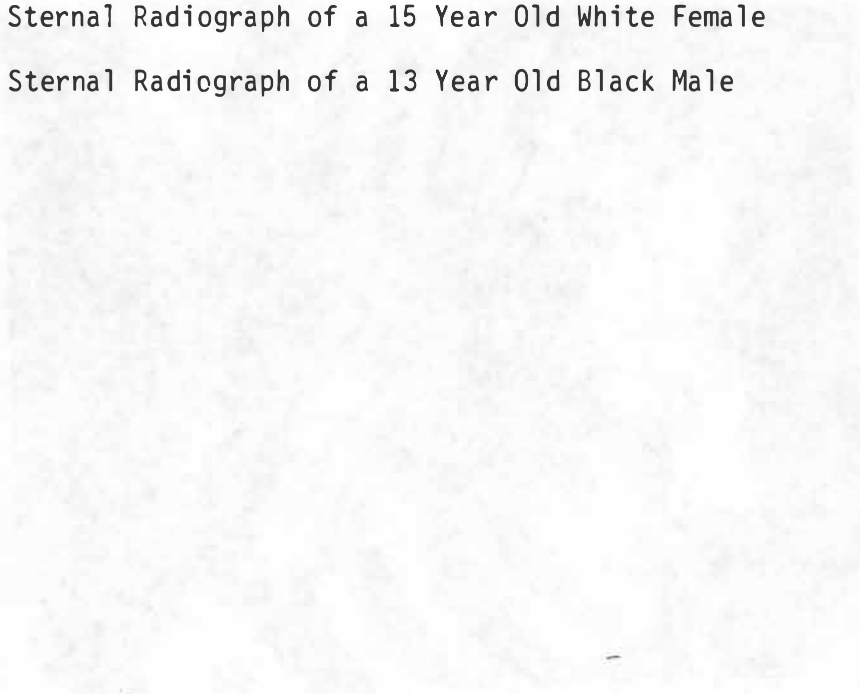


Figure 45

46. Sternal Radiograph of a 15 Year Old White Female

47. Sternal Radiograph of a 13 Year Old Black Male



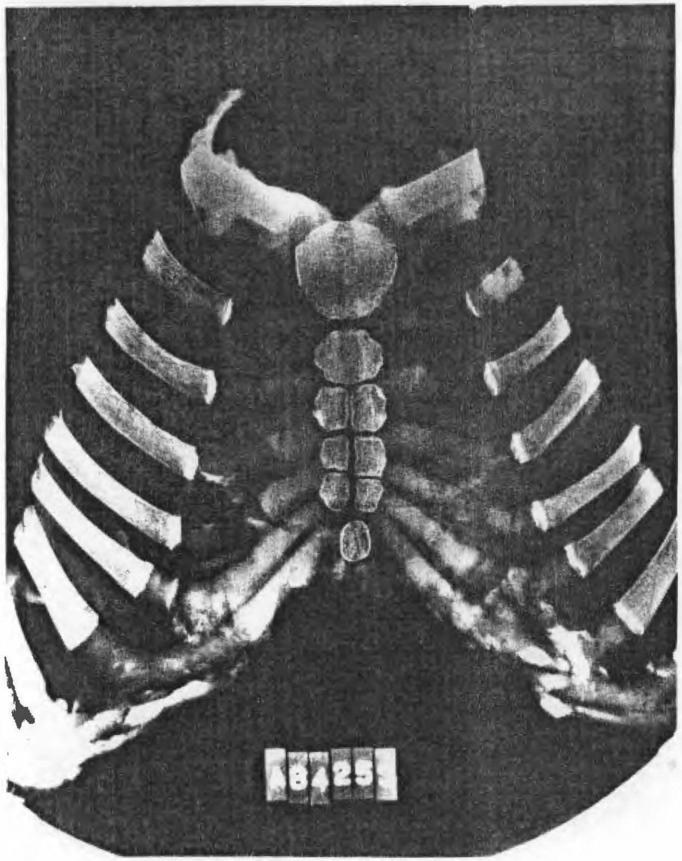


Figure 46

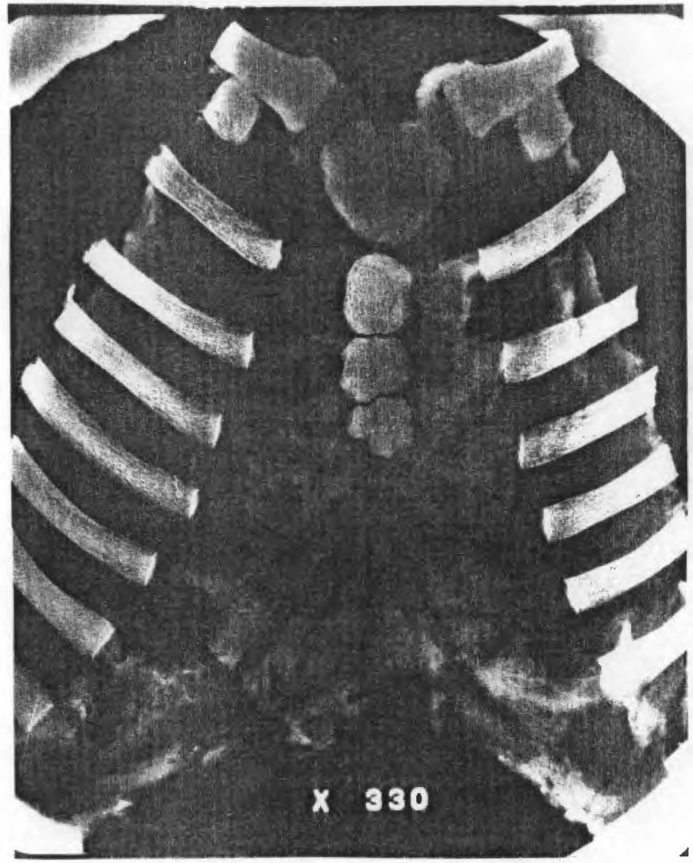


Figure 47

48. Sternal Radiograph of a 13 Year Old Black Male

49. Sternal Radiograph of a 14 Year Old Black Male

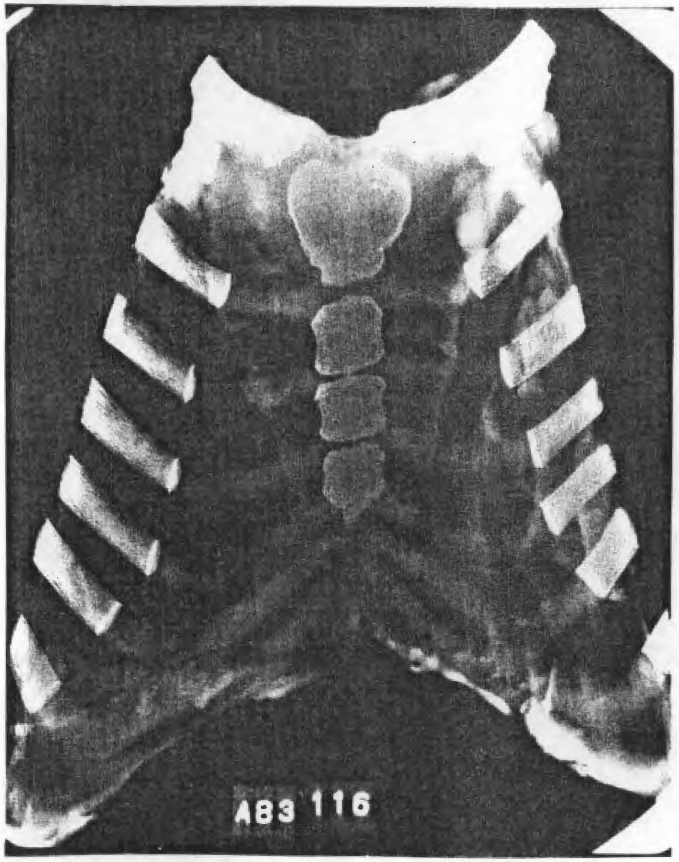


Figure 48

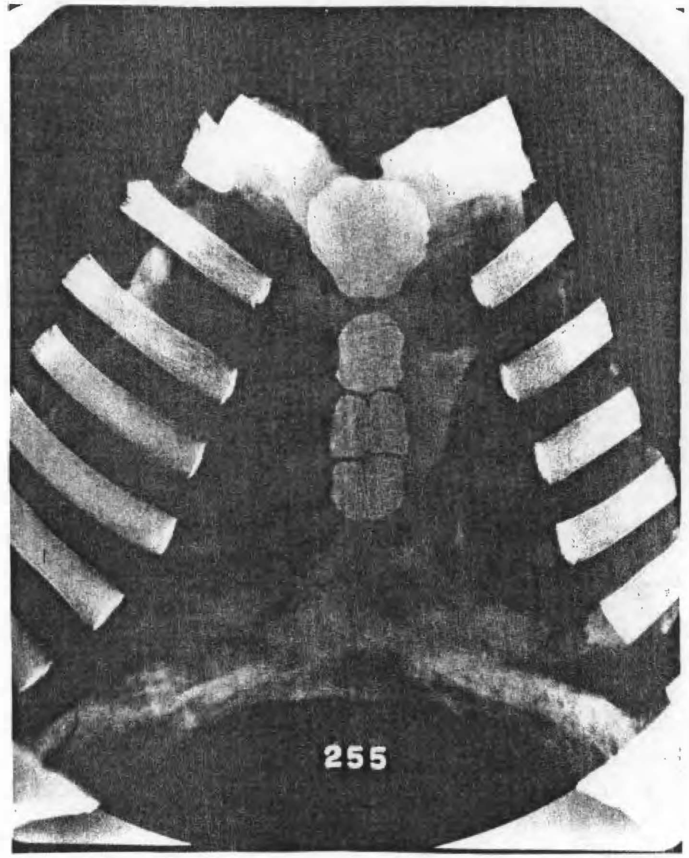


Figure 49

50. Sternal Radiograph of a 16 Year Old White Female, Considered to be of Normal Development with only Two Sternebrae

51. Sternal Radiograph of a 19 Year Old Black Female Born with Spina Bifida, Showing Premature Sternal Fusion and Sternal Foramina

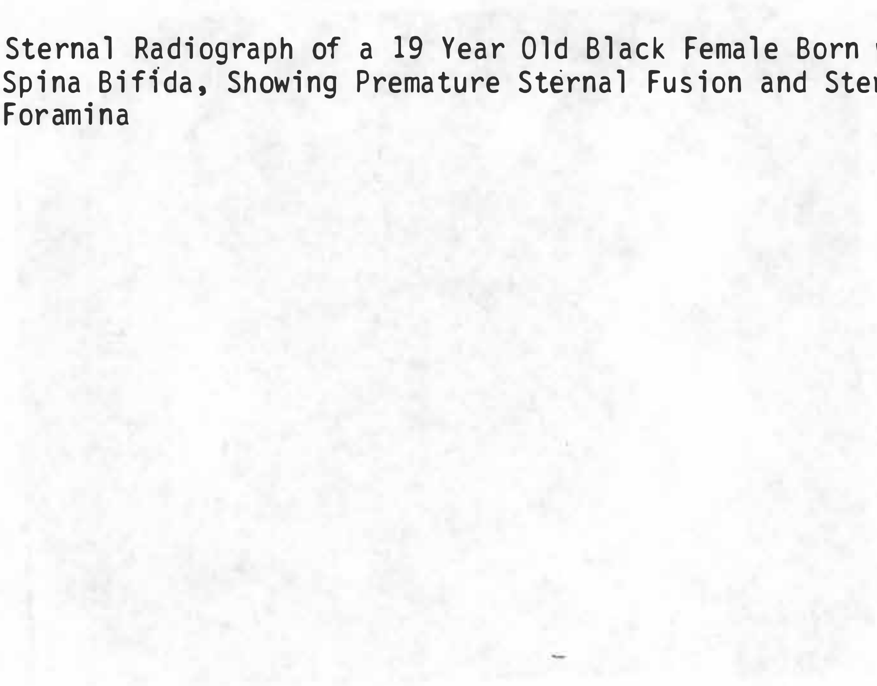


Figure 50

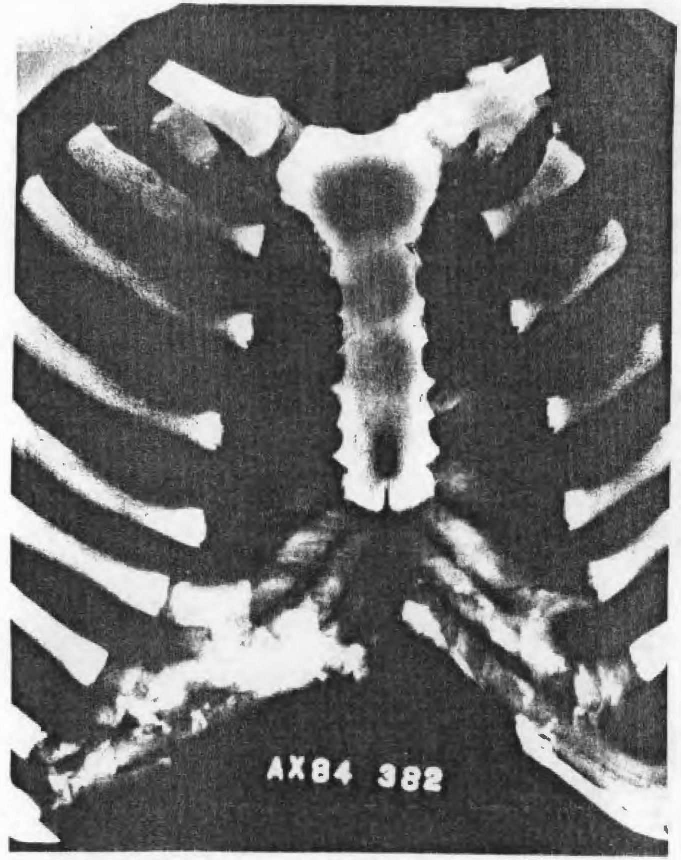
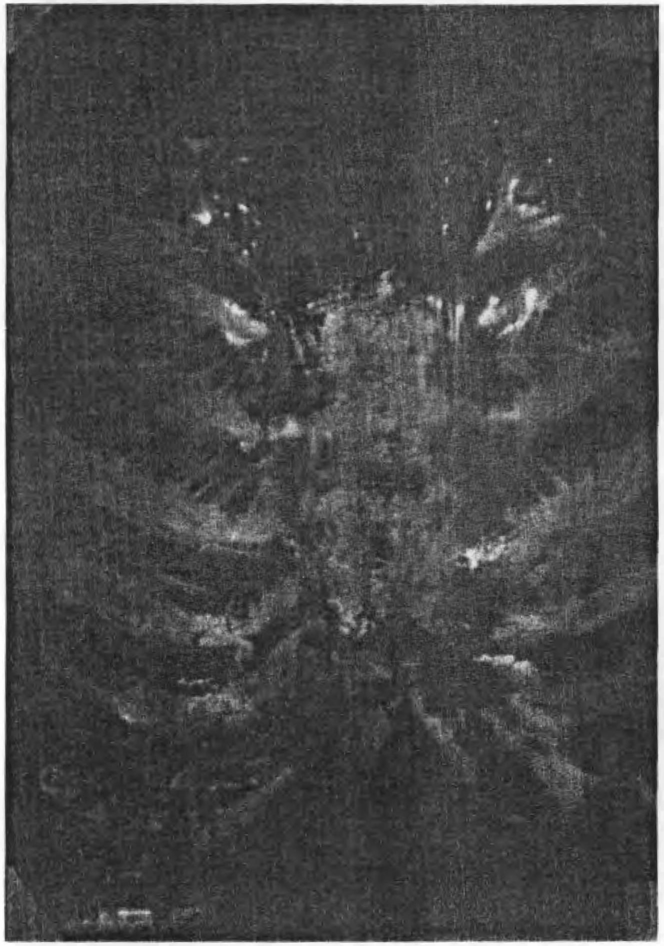


Figure 51

52. Chest Plate of a 19 Year Old Black Female Prior to Skeletalization

53. Close Up View of the Chest Plate of a 19 Year Old Black Female



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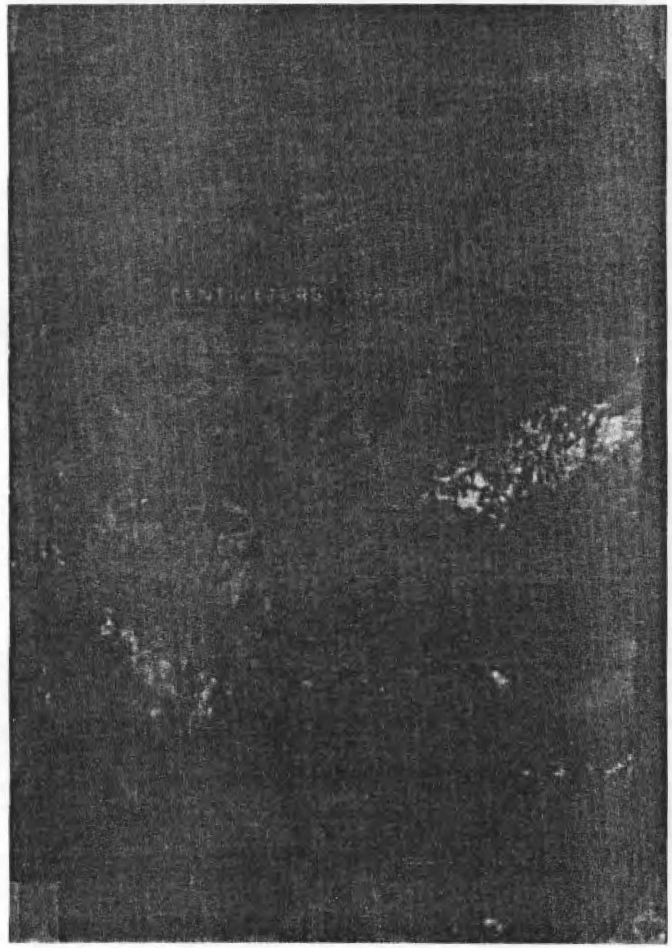
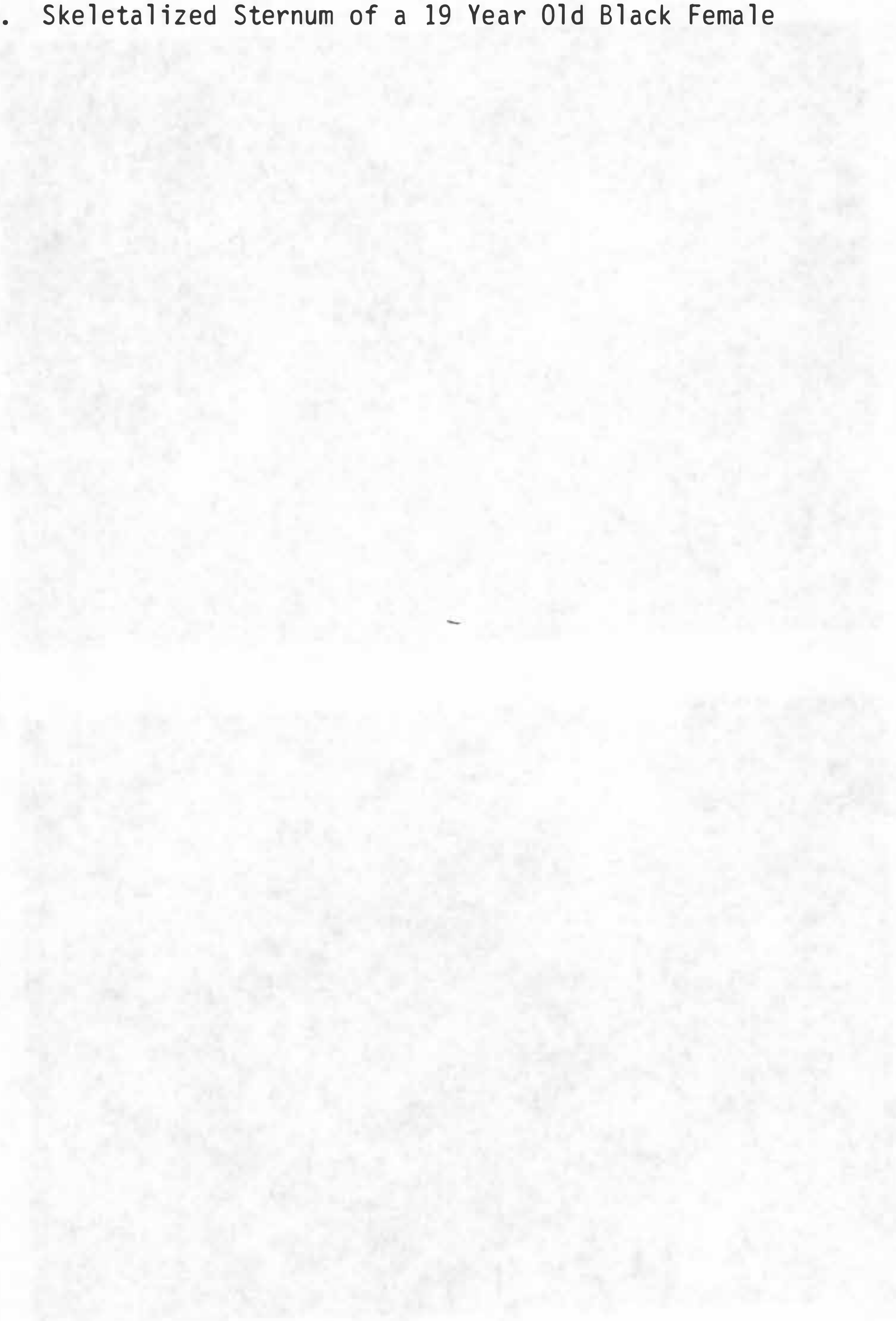


Figure 53

54. Skeletalized Sternum of a 19 Year Old Black Female



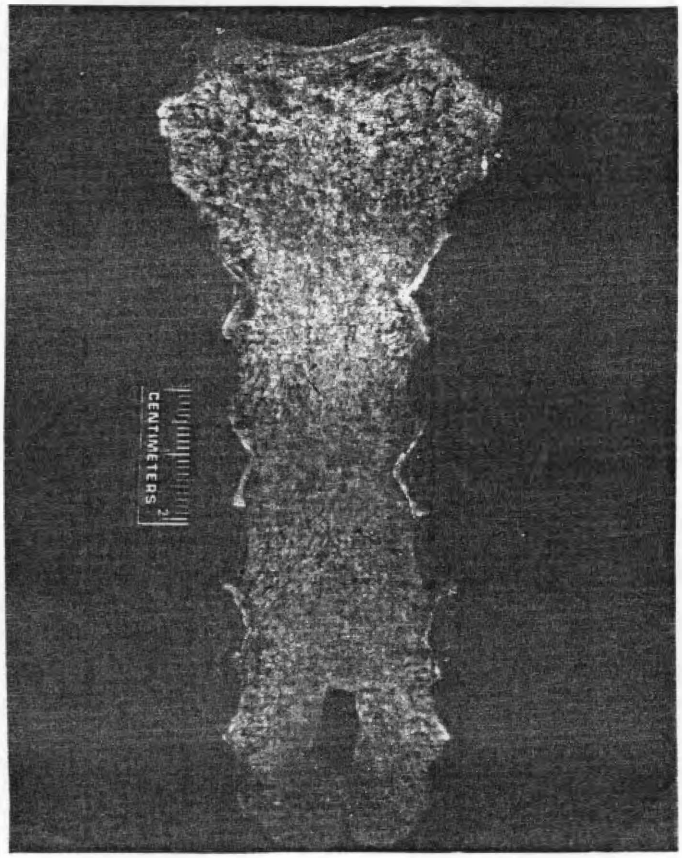


Figure 54

Figure 55. Graph Plot Showing the Mean and Maximum TO Values vs AGE

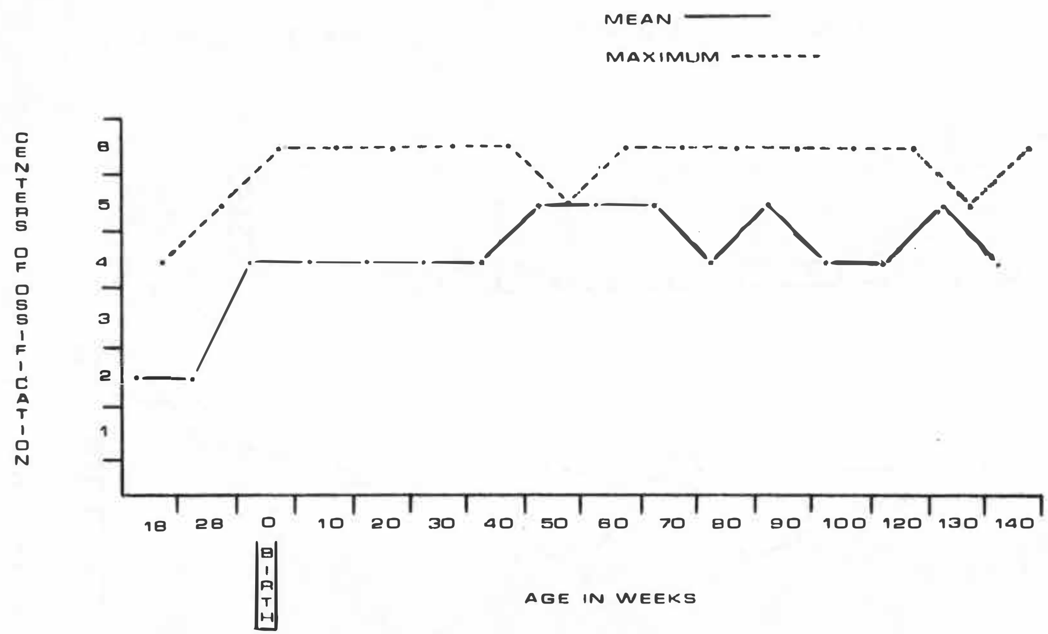


Figure 56. Graph Plot Showing the Mean and Maximum Z Values vs AGE

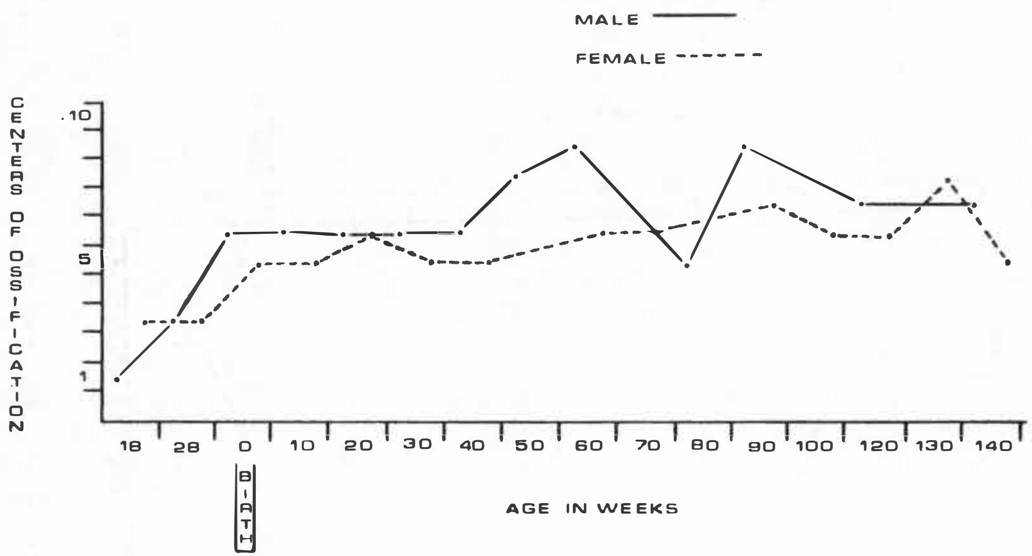


Figure 57. Graph Plot of TO Mean Values vs AGE by S

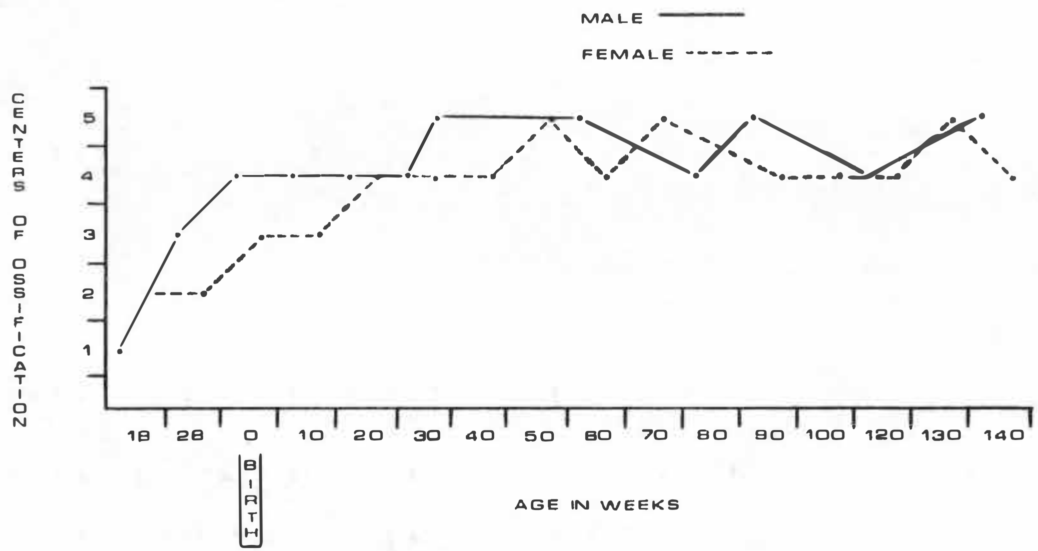


Table 58. Graph Plot of Z Mean Values vs AGE by S

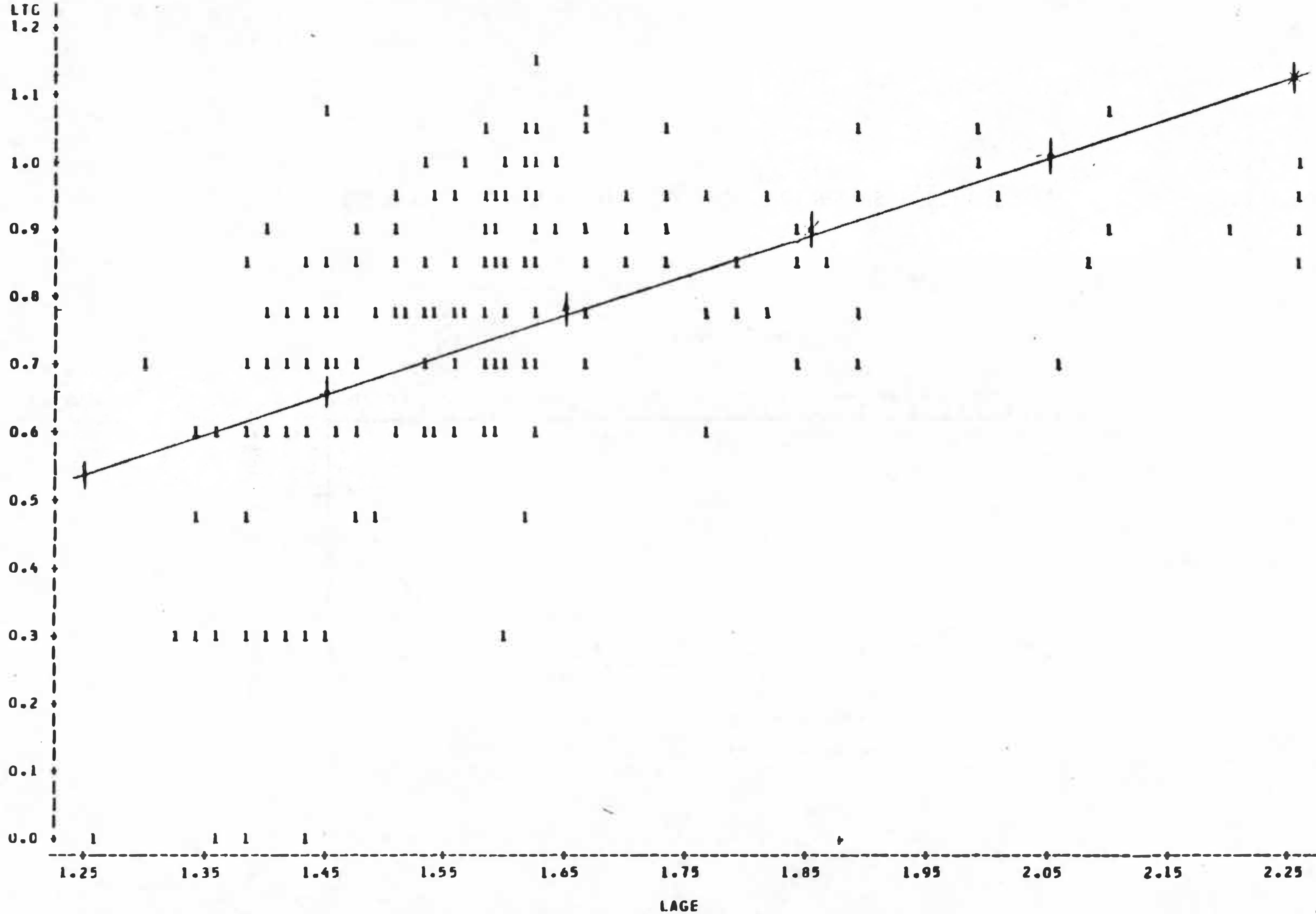


Figure 59. Regression Line Plot of Log TO vs Log AGE for Males

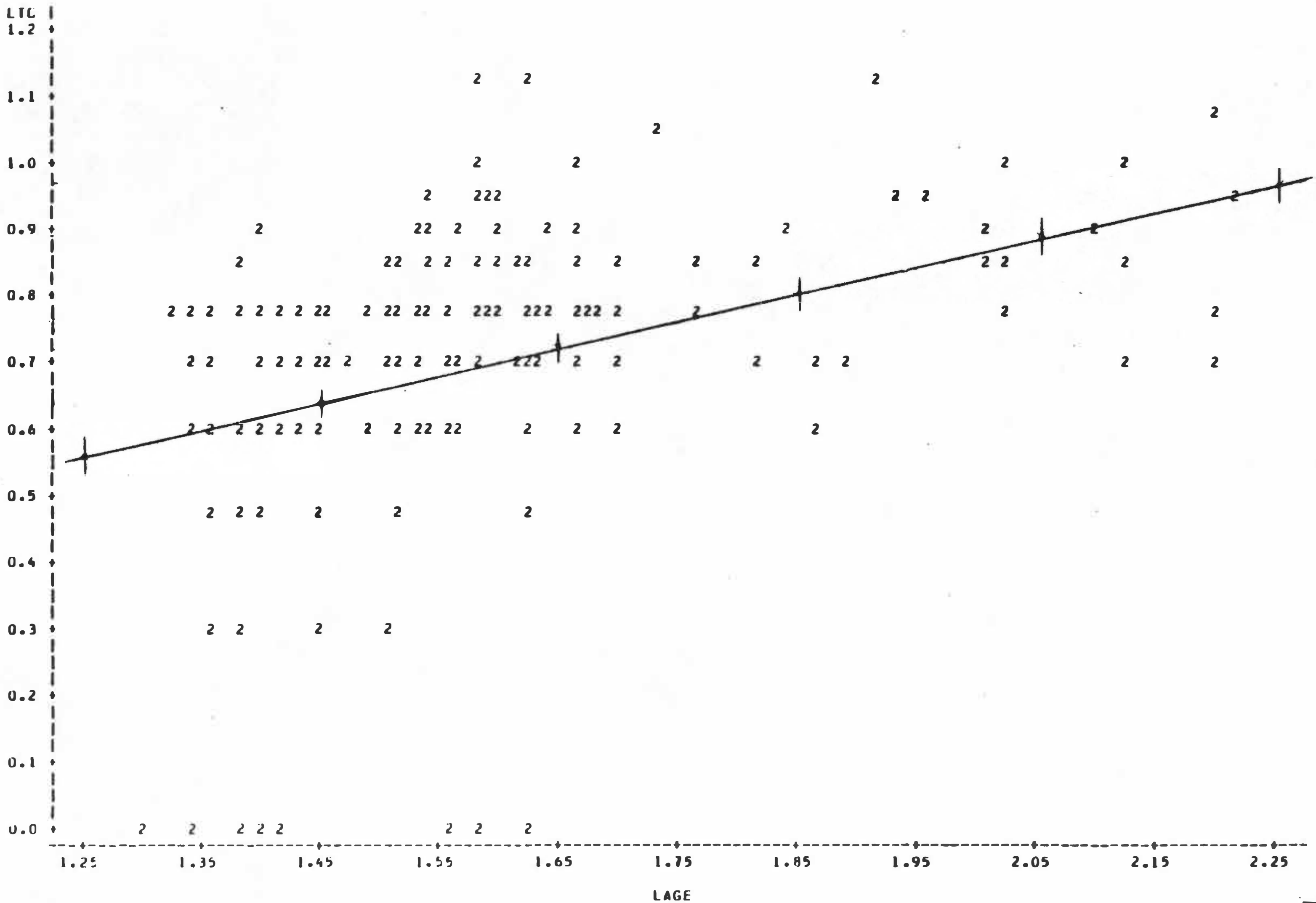


Figure 60. Regression Line Plot of Log TO vs Log AGE for Females

TABLES

Table 1. Computer File 1

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79180	9Y	00	W	M	X	00000	00	00	00	111110000000001000	TR
79183	3M	00	B	M	X	00000	00	00	00	111211000000000000	TR
79199	4Y	00	B	F	X	00000	00	00	00	211100000000000000	GD
79218	9Y	00	L	F	X	00000	00	00	00	111111000000110000	PH
79223	19Y	00	L	M	X	00000	00	00	00	111111000020202000	TR
79251	17Y	00	W	M	X	00000	00	00	00	111111001022020000	TR
79255	13Y	00	B	M	X	00000	00	00	00	112200000001010000	TR
79326	2D	29	W	F	P	1150	26	39	26	112000000000000000	TR
79327	12D	30	W	F	P	1230	30	40	00	211000000000000000	NO
79328	0B	36	L	M	P	2160	32	00	00	111100000000000000	MH
79330	13Y	00	B	F	X	00000	00	00	00	111200000000020000	TR
79332	7M	00	L	M	X	00000	00	00	00	111200000000000000	TR
79333	5D	28	W	F	P	860	25	35	25	120000000000000000	IA
79342	0B	34	L	M	P	1360	28	00	30	211000000000000000	AP
79348	14D	34	B	F	P	1600	31	44	29	111110000000000000	IA
79350	6M	00	L	M	X	00000	00	00	00	121110000200000000	CP
79355	0B	26	W	F	P	720	23	35	22	212000000000000000	IA
79366	0B	37	W	F	I	00000	00	00	00	112220000000000000	MD
79382	4D	33	B	F	P	1840	29	00	29	111000000000000000	MA
79383	1D	28	B	M	P	1060	30	42	27	211100000000000000	HM
79391	0B	31	B	M	P	1140	27	00	28	111201000000000000	IA
79396	1D	38	B	F	I	3100	33	00	34	111100000000000000	CH
79401	18D	28	B	F	P	890	25	38	25	111200000000000000	HM
79405	16Y	00	L	M	X	00000	00	00	00	111221000020222200	DD
80014	1D	25	B	M	P	670	22	34	21	111000000000000000	ID
80018	0B	40	A	M	I	2300	32	48	32	211100000000000000	ID
80045	5Y	00	W	M	X	00000	00	00	00	111200000000000000	MC
80049	5Y	00	W	M	X	00000	00	00	00	111100000010000000	RS
80055	36M	00	L	F	X	00000	00	00	00	211200020000000000	BP
80082	0B	36	L	M	P	1940	33	47	00	111300000000000000	MD
80088	6M	00	B	M	X	00000	00	00	00	111200000000020000	SD
80089	4Y	00	B	M	X	00000	00	00	00	211120020000000200	TR
80093	1D	27	W	M	P	910	24	36	23	112000000000000000	MF
80094	3D	40	B	M	I	3340	36	43	40	100000000000000000	DW
80098	0B	32	W	F	P	1130	27	41	28	211100000000000000	MF
80099	0B	25	W	F	P	600	21	29	23	001100000000000000	PI
80100	1D	25	W	M	P	640	22	32	22	111000000000000000	MF
80101	9M	00	W	M	X	00000	00	00	00	111300000000000000	BP
80105	11D	28	W	F	P	1010	25	39	26	110200000000000000	BC
80107	2M	40	W	F	I	2500	00	46	34	111000000000000000	DS
80108	0B	25	W	M	P	810	21	34	23	111100000000000000	NO
80112	0B	28	W	F	P	970	26	00	00	101100000000000000	PI
80113	0B	28	W	F	P	860	27	39	24	111000000000000000	PI
80114	7D	40	W	F	I	2700	35	41	32	111210000000000000	MM
80116	0B	24	W	F	P	930	22	00	24	111000000000000000	BD
80118	0B	36	W	F	P	1500	27	00	42	211000020000000000	AC
80119	0B	20	W	F	P	405	19	00	19	000000000000000000	PI
80124	3D	32	W	M	P	1180	28	00	27	112300000002000000	IA
80126	0B	38	W	M	I	2180	31	15	31	212300000000000000	PI
80128	9D	32	B	F	P	1480	28	00	24	110000000000000000	IA

Table 1. (Continued)

AUTOP	AGE	GA	R	S	B	WEIGH	CR	CH	HC	M12345XABCDEFGHIJK	MD
80147	0B	22	W	F	P	680	25	00	00	111100000000000000	MF
80149	0B	26	L	M	P	1080	27	00	26	111000000000000000	MF
80150	0B	32	B	M	P	2030	29	00	00	121200000000000000	MD
80162	0B	28	W	M	P	1070	24	36	27	111100000000000000	AP
80168	0B	28	W	F	P	1082	28	38	25	101000000000000000	AP
80169	0B	37	L	M	I	2950	33	50	33	111110000000000000	AP
80172	3D	35	L	F	P	1980	40	45	30	223100020000000000	SD
80174	2D	00	W	M	X	3400	37	51	00	421220000000000000	DS
80175	0B	40	W	M	I	2400	36	48	00	112220000002000000	ID
80176	1D	41	B	M	I	3100	36	56	33	111210000000000000	AP
80177	2M	00	B	F	X	4600	00	55	00	111220000000000000	GR
80178	2M	00	L	F	X	3470	39	54	33	111200000000000000	GR
80181	0B	40	B	M	I	3300	34	48	00	121100000000000000	IA
80187	7M	00	B	F	X	00000	00	00	00	111100000000000000	BP
80192	0B	28	W	M	P	1005	26	37	00	100000000000000000	IA
80199	1D	30	W	M	P	1390	27	42	27	122000000000000000	MF
80200	0B	27	B	M	P	880	24	35	23	212000000000000000	ID
80203	0B	25	W	F	P	880	25	37	00	112100000000000000	IA
80205	19Y	00	W	M	X	00000	00	00	00	111111001010202000	TR
80206	1D	26	B	M	P	620	27	34	22	100000000000000000	AP
80213	0B	25	B	M	P	650	23	34	00	100000000000000000	ID
80215	1M	33	B	M	P	1470	30	42	00	212220002000200000	KD
80216	0B	22	B	F	P	400	27	40	18	000000000000000000	AP
80218	0B	32	L	F	P	775	24	00	00	100000000000000000	MF
80220	0B	28	W	M	P	1270	28	00	00	111100000000000000	IA
80225	32M	00	B	F	X	00000	00	00	00	212210020000000000	MY
80227	4M	00	L	M	X	00000	00	00	00	112220000000000000	NO
80229	8Y	00	W	M	X	00000	00	00	00	211201020000220000	JB
80234	0B	40	W	F	I	3330	37	51	33	112300000000000000	ID
80238	0B	23	B	F	P	370	18	26	19	100000000000000000	ID
80239	0B	23	B	F	P	470	20	29	20	110000000000000000	ID
80242	1D	00	L	M	X	3920	36	51	33	111110000000000000	CD
80244	2M	00	B	M	X	3040	34	49	00	112210000002000000	SD
80247	0B	38	L	M	I	3590	39	53	38	111110000010202000	DW
80248	0B	37	L	F	I	2200	33	46	31	111100000000000000	ID
80249	0B	37	L	F	I	2210	33	48	30	111000000000000000	ID
80250	0B	36	W	M	P	2820	35	51	34	111201000000220000	MF
80252	0B	00	W	M	X	3300	38	55	34	112210000000000000	NO
80254	0A	18	B	M	P	320	18	27	18	000000000000000000	AP
80260	11D	28	B	M	P	760	25	35	25	111000000000000000	NO
80267	0B	22	W	F	P	570	22	32	22	112100000000000000	ID
80270	14D	00	W	F	X	4100	00	56	41	311111020010201020	IA
80277	0B	34	W	M	P	2110	32	47	31	111200000000000000	AP
80286	0B	24	B	F	P	870	25	37	23	122100000000000000	AP
80287	0B	44	B	M	A	3960	56	42	38	222211000200000000	MF
80289	0B	22	W	M	P	570	22	32	19	100000000000000000	NO
80293	0B	21	B	F	P	400	20	29	20	112100000000000000	AP
80299	0B	41	B	M	I	00000	00	00	00	110000000000000000	BP
80300	7M	00	W	M	X	00000	00	00	00	112301000002000000	BP
80306	2D	25	B	F	P	670	23	37	23	111000000000000000	RS
80307	1D	26	W	F	P	750	24	36	24	111000000000000000	TA
80309	0B	38	B	M	I	3000	35	00	00	111221000000000000	HY
80312	2D	26	W	M	P	750	23	34	23	112000000000000000	NO
80313	0B	33	W	F	P	1410	29	41	27	111200000000010000	NO

AUTOP	AGE	GA	R	S	B	WEIGH	CR	CH	HC	M12345XABCDEFGHIJK	MD
80320	1D	28	W	M	P	1250	28	41	27	111100000000000000	NO
80322	0B	30	W	M	P	1300	27	38	25	212200000000000000	AP
80324	0B	32	W	F	P	1200	28	40	27	111100000000000000	CA
80325	23D	31	W	M	P	1180	27	00	27	111200000000000000	RS
80332	22M	00	W	M	X	00000	00	00	00	412310020000000000	TR
80627	17M	00	W	F	X	00000	00	00	00	111111000010202000	TR
81002	9M	00	B	M	X	00000	00	00	00	111111000000000000	NO
81004	4M	00	L	M	X	00000	00	00	00	111220000000000000	SD
81007	1D	24	B	M	P	510	10	19	21	100000000000000000	ID
81008	0B	24	B	F	P	450	19	28	19	100000000000000000	ID
81010	8D	30	L	M	P	960	24	00	25	111100000000000000	NO
81013	0B	24	B	F	P	770	24	34	22	110000000000000000	DS
81014	0B	33	B	F	P	1600	31	44	32	220000000000000000	NO
81018	0B	33	W	F	P	2040	31	46	31	111300000000000000	MF
81022	0B	00	B	M	X	3360	40	57	31	111200000000000000	AP
81024	4Y	00	W	F	X	00000	00	00	00	211100000200010000	MG
81028	0B	25	B	F	P	600	22	00	22	211000000000000000	PI
81029	12Y	00	W	M	X	00000	00	00	00	111210000000122000	LL
81032	4M	00	W	M	X	00000	00	00	00	411100010000000000	MG
81036	0B	36	W	F	P	2250	32	49	32	121100000200000000	PI
81040	21M	00	B	M	X	00000	00	00	00	111111000000000000	WD
81046	0B	37	B	M	I	2000	33	49	32	112100000000000000	AP
81057	21M	00	B	M	X	00000	00	00	00	112200000002000000	SS
81073	3M	00	L	F	X	00000	00	00	00	111200000000010000	DS
81084	0B	26	L	M	P	670	23	00	23	111110000000000000	NO
81091	0B	22	W	M	P	500	20	31	21	111000000000000000	PI
81100	21D	00	L	M	X	00000	00	00	00	111100000000200000	SD
81128	4Y	00	B	M	X	00000	00	00	00	211100020000000000	NB
81133	10Y	00	L	M	X	00000	00	00	00	111211000000022000	TR
81136	0B	00	L	M	X	3530	36	55	34	222210000000000000	NO
81144	0B	38	W	M	I	2480	35	50	00	311221010000000000	NO
81152	2M	33	W	M	P	1480	00	38	28	111200000000000000	GS
81172	18Y	00	W	M	X	8000	54	96	00	111210000000202000	CP
81174	0B	37	W	M	I	2918	34	49	35	111111000000000000	AP
81184	17Y	00	L	F	X	00000	00	00	00	111110002020202000	GA
81186	19Y	00	W	F	X	00000	00	00	00	111110000010102000	TR
81192	0B	42	W	F	I	3850	38	00	30	211110000000000000	CA
81200	8Y	00	B	F	X	00000	00	00	00	111111000001010000	PC
81205	0B	34	W	F	P	1860	30	44	31	111200000000000000	NO
81221	16M	00	B	F	X	00000	00	00	00	112200000000000000	TR
81235	2M	27	W	F	P	1210	26	39	27	112000000000000000	CI
81237	1D	35	W	F	P	2500	00	00	00	112120000000000100	SP
81238	2D	27	W	M	P	900	23	35	25	100000000000000000	NO
81256	0B	42	B	M	I	4000	37	54	34	112200000000000000	PI
81269	0B	35	W	F	P	1940	18	31	00	111000000000000000	PI
81283	2D	24	B	F	P	585	21	33	22	110000000000000000	NO
81285	16M	00	B	M	X	00000	00	00	00	111311000000020000	TR
81287	15Y	00	B	M	X	00000	00	00	00	111111000000202000	TR
81289	4M	00	L	F	X	00000	00	00	00	111331000000000000	RS
81298	1D	41	W	M	I	3400	36	53	37	111241000000000000	BP
81302	4Y	00	W	F	X	00000	00	00	00	111111000000002000	LL
81323	4Y	00	B	F	X	00000	00	00	00	112221000000000000	MC
81340	19M	00	W	M	X	00000	00	00	00	111100000000000000	GA
81345	3M	00	W	F	X	00000	00	00	00	211110000000000000	BC

Table 1. (Continued)

AUTOP	AGE	GA	R	S	B	WEIGH	CR	CH	HC	M12345XABCDEFGHIJK	MD
82004	18Y	00	L	M	X	00000	00	00	00	111100000030300000	TR
82008	18Y	00	A	M	X	00000	00	00	00	111110000020303000	TR
82015	24M	00	W	F	X	00000	00	00	00	112110000002000000	OD
82027	4Y	00	W	M	X	00000	00	00	00	111110000020202000	CF
82039	14D	32	L	F	P	1615	28	43	52	111112000000120000	MM
82043	0B	42	L	F	I	2555	36	53	37	211110000000002000	PI
82045	0B	27	L	M	P	905	26	39	23	111110000000000000	AP
82060	2D	28	B	M	P	1080	25	37	27	111001000000000000	CA
82062	13Y	00	W	M	X	00000	00	00	00	111101000010100000	RS
82065	1D	37	W	M	I	1200	43	29	31	111000000000000000	PH
82069	14Y	00	L	M	X	00000	00	00	00	111110000000001000	JP
82073	2D	27	L	F	P	890	24	35	24	111100000000000000	CA
82076	0B	38	B	M	I	1970	46	31	30	111220000000000000	PI
82084	14Y	00	L	F	X	00000	00	00	00	111110000020201000	SP
82085	3D	32	B	M	P	1440	29	42	29	112200000000000000	CI
82087	16Y	00	W	M	X	00000	00	00	00	111110000020303000	LB
82096	15Y	00	L	F	X	00000	00	00	00	111111000020303030	MG
82103	8M	00	W	M	X	00000	00	00	00	111220001020000000	SD
82114	14Y	00	W	M	X	00000	00	00	00	111111000000202020	PW
82118	3M	00	W	F	X	2180	00	33	46	111000000020300000	BD
82125	2M	00	B	M	X	00000	00	00	00	111300000000000000	SD
82129	24M	00	B	F	X	00000	00	00	00	311220020000000000	DN
82135	24M	00	W	M	X	00000	00	00	00	232220002020000000	TR
82136	1M	00	B	F	X	3000	00	00	00	146100000100000000	TS
82139	0B	36	L	F	P	00000	00	00	00	111000000000000000	MF
82140	36M	00	W	M	X	00000	00	00	00	211111020000100000	SD
82149	9D	26	W	M	P	855	24	36	25	111000000000000000	MF
82150	36M	00	W	M	X	00000	00	00	00	113210000002000000	TR
82159	7D	37	L	M	I	2405	33	48	34	111100000000200000	CA
82169	10M	00	B	M	X	00000	00	00	00	111100000000000000	SD
82181	2D	00	W	M	X	3930	56	35	37	413321020000001000	CD
82188	16Y	00	L	F	X	00000	00	00	00	111100000020300000	LE
82189	24M	00	W	F	X	00000	00	00	00	111100000000000000	TR
82193	1D	38	B	M	I	3050	35	49	00	111000000000000000	NO
82210	24D	28	B	F	P	1495	28	44	34	111000000000000000	RD
82211	18Y	00	L	M	X	00000	00	00	00	111111000030303000	TR
82224	10M	00	B	M	X	11300	00	00	00	111221000000000000	TR
82228	0B	42	B	M	I	5005	56	41	37	112221000000000000	IA
82234	2D	41	W	F	I	3120	37	54	34	111210000000000000	NO
82236	0B	34	W	M	P	2100	47	33	33	131100000000000000	PI
82245	0B	28	L	M	P	00000	41	28	00	111120000000000000	MF
82248	0B	38	L	M	I	2725	35	51	00	111200000000000100	NO
82257	17M	00	W	F	X	12100	00	00	00	112320000000000000	TR
82258	17M	00	W	F	X	11340	00	00	00	211100020000000000	LB
82260	8M	00	L	F	X	00000	00	00	00	111211000000000000	CD
82270	5M	00	L	F	X	00000	00	00	00	211100010000000000	HY
82272	0B	32	W	M	P	1020	31	25	26	111000000000000000	PH
82273	0B	34	B	M	P	2010	30	47	29	111000000000000000	CA
82274	11Y	00	W	F	X	00000	00	00	00	111010000010100000	ML
82275	0B	33	B	F	P	1700	28	41	29	101000000000000000	ID
82281	0B	34	W	F	P	1550	29	41	27	112100000000000000	MY
82283	4Y	00	L	M	X	00000	00	00	00	412210020000000000	SD
82286	8M	00	B	M	X	2290	31	44	00	111201000000000000	ID
82287	0B	37	W	M	I	2041	35	47	30	111110000000001000	PI

Table 1. (Continued)

AUTOP	AGE	GA	R	S	B	WEIGH	CR	CH	HC	M12345XABCDEFGHIJK	MD
82295	1D	26	W	F	P	990	23	00	00	210000020000000000	OD
82297	7D	00	W	M	X	00000	00	00	00	111210000000000000	ID
82298	0B	34	W	M	P	1550	40	28	30	111110000000000000	PI
82303	0B	28	B	M	P	1030	27	40	25	212100000000000000	PI
82304	7Y	00	B	F	X	24040	00	00	00	111000000000000000	DH
82309	SB	43	L	F	X	3030	36	51	00	111200000000000000	NO
82313	4Y	00	B	F	X	00000	00	00	00	111110000000002000	CP
82324	5M	00	W	M	X	00000	00	00	00	121220002010202200	SD
82325	5M	00	W	F	X	3350	56	36	00	111200000000000000	DW
82326	1D	27	B	F	P	900	37	25	25	111200000000000000	HM
82331	36M	00	W	M	X	8860	00	89	45	222120000202000200	ID
83015	0B	39	L	M	I	2540	33	52	32	211211020000020000	PI
83016	3M	00	L	F	X	00000	00	00	00	111100000000000000	MY
83021	0B	35	W	F	P	1560	27	42	27	111200000000000000	MD
83025	3D	40	W	M	I	3400	34	50	34	114200000000000000	GA
83029	0B	40	B	M	I	2060	29	50	29	111010000000000000	MA
83030	1D	36	W	M	P	2450	33	00	33	222200000202000000	SP
83031	5M	00	B	F	X	3200	36	51	35	311100000000000000	HM
83032	19Y	00	L	M	X	00000	00	00	00	111101000000200000	NB
83034	0B	36	W	F	P	1010	13	28	00	000000000000000000	AC
83035	11M	00	L	F	X	00000	00	00	00	311133002020022220	SP
83041	18Y	00	B	F	X	00000	00	00	00	111110000030300000	TR
83045	1D	23	B	M	P	700	22	32	23	100000000000000000	IA
83054	11Y	00	W	F	X	32800	00	00	00	111110000000100000	JD
83059	0B	23	B	F	P	550	20	28	20	111000000000000000	ID
83067	12M	00	W	F	X	00000	00	00	00	311210020000000000	DS
83072	0B	23	L	M	P	540	20	29	20	111000000000000000	MF
83075	0B	30	W	M	P	1005	00	35	25	131200000000000000	MF
83079	0B	30	B	M	P	1300	41	28	25	200000000000000000	ID
83087	0B	23	W	F	P	560	20	31	21	112000000000000000	ID
83088	0B	29	W	M	P	980	27	39	27	122000000000000000	PI
83089	1D	25	B	M	P	690	22	32	23	211100000000000000	NO
83098	1D	24	W	M	P	590	22	32	22	100000000000000000	ID
83099	0B	24	A	M	P	750	22	32	23	110000000000000000	IA
83100	3D	40	W	F	I	2620	34	50	34	121200000200000000	CP
83102	7M	00	B	F	X	00000	00	00	00	311100000000000000	SM
83104	23D	30	B	F	P	1360	27	41	27	112200000000000000	SM
83106	2D	00	W	M	X	900	00	35	25	111000000000000000	NO
83109	2D	41	W	M	I	3990	39	55	38	212320031003010000	ID
83111	0B	24	B	M	P	565	21	31	21	000000000000000000	NO
83113	0B	24	W	M	P	620	21	32	23	211110000000000000	PI
83116	14Y	00	B	M	X	00000	00	00	00	111100000100000000	ES
83119	0B	32	W	M	P	1630	30	42	28	112210000000000000	NO
83121	2D	00	B	F	X	1600	28	42	33	311000030000000000	CP
83121	0B	20	B	M	P	580	20	32	20	112000000000000000	BH
83125	1D	40	L	M	I	4350	36	52	41	121100000000000000	HY
83128	0B	29	L	M	P	650	22	33	20	111100000000000000	PI
83129	1D	25	W	F	P	590	21	35	22	110000000000000000	NO
83131	0B	20	B	F	P	440	20	28	18	000000000000000000	CP
83132	0B	00	L	F	X	2900	36	53	33	311100020000000000	NO
83138	0B	24	W	M	P	630	21	31	23	010000000000000000	PI
83139	0B	24	W	M	P	310	17	23	30	000000000000000000	PI
83140	0B	42	W	M	I	2800	33	57	34	222100010100000000	NO
83145	16M	00	L	F	X	00000	00	00	00	311101022030300000	ID

Table 1. (Continued)

AUTOP	AGE	GA	R	S	B	WEIGH	CR	CH	HC	M12345XABCDEFGHIJK	MD
83146	0B	25	W	F	P	676	22	33	23	111000000000000000	IA
83149	36M	00	W	F	X	00000	00	00	00	111200000000000200	TR
83151	0B	32	W	M	P	1300	25	35	28	212210020002000000	ID
83155	0B	37	B	F	I	2080	32	53	31	111101000000000000	NO
83162	1M	00	W	M	X	4670	34	54	36	212131030000000000	BP
83164	0B	24	W	F	P	530	20	30	21	111110000000000000	ID
83165	0B	25	W	M	P	890	24	36	23	111000000000000000	AP
83168	17Y	00	W	F	X	00000	00	00	00	111110002020001000	CP
83170	6Y	00	W	M	X	22680	00	00	00	111221000000022200	ID
83171	16Y	00	W	F	X	00000	00	00	00	111100000030000000	TR
83172	14D	00	B	F	X	2860	34	46	33	112220000000000000	DS
83173	30M	00	B	M	X	13300	00	00	50	122200003303000000	LB
83175	1D	25	B	M	P	940	23	31	25	100000000000000000	MM
83176	1D	29	A	F	P	1790	28	40	27	111200001000010000	NO
83178	10M	00	B	M	X	4960	29	63	41	212221000000000000	BD
83183	1D	24	W	M	P	550	21	33	21	100000000000000000	TR
83184	16Y	00	W	M	X	00000	00	00	00	111100000023000000	TR
83185	30M	00	W	F	X	12700	61	00	49	412211020000030000	BP
83188	0B	37	B	M	I	2240	33	49	33	111100000000000000	PI
83189	0B	28	B	F	P	810	23	35	24	100000000000000000	PI
83190	2M	00	L	M	X	5620	42	62	00	112120000000000000	CT
83194	0B	37	L	M	I	3920	35	42	36	111111001020100100	DW
83197	1D	34	W	M	P	1730	30	45	27	111100000000000000	ID
83199	30M	00	B	F	X	14061	56	89	51	111100000000000000	MG
83202	1M	38	W	F	I	2860	00	54	35	122100000000000000	CD
83203	4D	30	W	M	P	1150	25	36	27	121200000000000000	NO
83205	2M	00	L	F	X	2440	32	50	31	211000000000000000	DS
83208	0B	29	W	M	P	920	26	39	21	111111000000000000	ID
83210	0B	28	W	M	P	1340	28	00	00	111201000000000000	ID
83211	1D	38	W	F	P	5500	42	59	38	323220000000000300	ID
83213	0B	22	W	F	P	560	21	32	22	111000000000000000	ID
83214	0B	30	W	M	P	1520	26	39	28	111000000000000000	ID
83220	30M	00	W	F	X	00000	00	00	00	112100001003000000	GR
83231	16Y	00	W	M	X	00000	00	00	00	111111000010200200	GR
83233	2M	00	W	F	X	00000	00	00	00	312100000000000000	ID
83234	0B	00	B	M	X	3240	35	00	00	211101020000000000	IA
83236	0B	24	W	M	P	600	21	00	00	211000000000000000	MM
83237	0B	24	W	F	P	380	18	00	00	110000000000000000	MM
83240	0B	30	B	F	P	820	23	35	23	400000000000000000	PI
83241	0B	26	L	F	P	435	19	28	18	111000000000000000	ID
83243	13M	00	W	F	X	00000	00	00	00	131210000200001000	GR
83245	1D	27	W	M	P	850	21	34	24	112200000000000000	CA
83246	0B	26	W	F	P	720	22	22	00	000000000000000000	MM
83247	1D	00	B	M	X	3628	00	00	00	111100000000000000	ID
83248	1D	24	W	F	P	640	19	31	22	000000000000000000	ID
83253	0B	22	W	M	P	320	00	00	00	110000000000000000	ID
83254	0B	25	W	F	P	740	21	34	22	111000000000000000	ID
83259	0B	23	L	M	P	700	22	34	21	111000000000000000	ID
83263	3M	00	B	F	X	3750	38	56	40	111000000000000000	PW
83264	0B	32	B	F	P	1480	28	42	29	112100000001000000	ID
83266	4D	00	W	F	X	2190	31	47	32	111100000000000000	CD
83269	5M	00	W	F	X	5360	43	65	40	111110000000000000	SD
83272	9M	00	W	F	X	5900	00	64	41	112000000000000000	MY
83274	24M	00	B	F	X	15000	00	00	00	112221000000020000	TR

AUTOP	AGE	GA	R	S	B	WEIGH	CR	CH	HC	M12345XABCDEFGHIJK	MD
83280	4D	35	B	F	P	2270	30	45	24	12220000002000000	MM
83282	1M	37	W	F	I	2870	30	49	00	212200030002010000	MM
83287	3D	41	B	F	I	3303	36	53	36	211001030000000000	ID
83291	2M	00	W	M	X	5780	50	62	41	221321000300010000	SD
83294	3M	00	W	F	X	00000	00	00	00	111100000000000000	SP
83296	1D	34	L	F	P	2630	32	52	33	111200000000000000	KD
83297	0B	27	L	F	P	1020	24	37	25	111100000000000000	ID
83298	0B	25	W	F	P	710	22	32	23	212000000000000000	ID
83303	2M	00	B	F	X	4820	42	59	41	212220030002000000	SD
83304	0B	34	B	F	P	1960	31	45	30	111000000000000000	ID
83317	4M	34	L	F	X	4270	38	54	42	111110000000000000	HY
83318	7Y	00	W	F	X	20000	00	00	53	111100000000200000	TR
83322	0B	30	W	M	P	1300	27	38	25	111000000000000000	AP
83323	1D	36	W	F	P	2850	34	51	33	121200000000000000	ID
83325	3M	00	L	M	X	4330	33	52	38	212210000000000000	VS
83327	2M	36	W	F	P	3480	35	52	37	112200000000000000	MM
83328	22M	00	W	M	X	14000	25	00	48	111211000000000000	MM
83332	0B	27	W	M	P	987	26	38	27	122000000000000000	ID
83333	7M	00	B	F	X	5550	44	67	40	111100000000000000	SD
83335	5M	26	W	M	X	4630	00	57	38	112210000000000000	MM
83337	1M	35	L	M	P	2500	30	47	31	111201000000000000	CT
83338	0B	36	W	M	P	2180	33	49	30	111000000000000000	ID
83339	1D	00	W	F	X	2190	31	42	36	000000000000000000	DW
83340	1D	38	W	F	I	2840	34	49	33	111200000000020000	RD
83343	1D	00	W	M	X	00000	00	00	00	211100000000000000	CH
83345	1D	22	W	M	P	545	22	00	00	210000000000000000	ID
83356	12D	00	W	M	X	00000	00	00	00	312210000000000000	HY
83357	25D	28	W	M	P	840	26	35	27	110000000000000000	ID
83358	14Y	00	W	F	X	19000	00	00	51	111100002020200000	CP
83359	2M	00	L	M	X	5900	42	57	40	111200000000030000	SD
83363	2M	00	W	F	X	00000	00	00	00	300000000000000000	MG
83368	5D	00	B	M	X	2013	30	44	30	111100000000000000	DS
83370	2M	00	W	M	X	00000	00	00	00	233200002020000000	SD
83371	0B	00	L	F	X	00000	00	00	00	110000000000000000	PS
83377	0B	22	W	M	P	495	21	31	21	100000000000000000	AP
83382	0B	34	L	F	P	1725	32	42	29	111000000000000000	AP
83386	4Y	00	W	M	X	00000	00	00	00	111111000000000000	HT
84002	2M	00	W	F	X	2250	33	45	32	422100030100000000	NO
84004	1D	00	W	F	X	3860	38	57	49	111100000000000000	MM
84005	0B	00	L	M	X	4840	36	64	00	111211000000020000	ID
84006	4D	26	B	F	P	710	20	32	10	111000000000000000	ID
84011	0B	34	L	M	P	1390	29	00	33	211100002000001000	ID
84019	4M	00	W	M	X	00000	00	00	00	112200000000010000	SD
84022	0B	39	B	M	I	2800	37	54	34	122211000000000000	CS
84023	1M	00	L	M	X	4620	31	51	37	312200000003000000	ID
84032	1D	27	W	F	P	740	22	34	20	111100000000000000	ID
84037	3M	00	W	F	X	5660	42	62	00	111100000000000000	SD
84040	8M	00	W	M	X	00000	70	41	00	101101000000000000	SM
84041	0B	34	W	M	P	1630	28	46	00	322200030000000000	ID
84042	0B	37	L	M	I	2190	33	48	32	312300000000000000	ID
84046	0B	39	W	F	I	1850	32	45	00	111200000000030000	ID
84048	3M	00	L	M	X	23000	58	94	52	221100003000000000	PW
84050	0B	22	W	F	P	580	21	00	00	112000000002000000	ID
84051	21D	00	W	F	X	3750	38	56	00	211110030000000000	SD

AUTOP	AGE	GA	R	S	B	WEIGH	CR	CH	HC	M12345XABCDEFGHIJK	MD
84058	10M	00	W	F	X	00000	00	00	00	111100000000000000	TR
84059	1M	00	L	M	X	4130	00	53	36	622000000300000000	MM
84061	1D	34	L	M	P	1930	30	44	00	111200000000000000	ID
84063	1D	00	W	M	X	4366	38	56	37	213210030000010000	CH
84067	22M	00	W	F	X	00000	85	49	00	311200020000003000	NC
84068	0B	40	W	M	I	3450	38	53	35	111112000000000000	ID
84072	24M	00	W	F	X	00000	00	00	00	111100000010200000	MG
84074	15Y	00	B	F	X	00000	00	00	00	122200000000000000	PW
84076	0B	39	W	F	I	3100	34	51	36	111200000000000000	ID
84077	2M	37	B	M	I	2700	36	54	36	112320000000011000	NO
84084	0B	32	W	F	P	1190	28	41	24	212100030001000000	ID
84088	6Y	00	L	M	X	00000	00	00	00	111220000000320000	MS
84090	0B	33	B	F	P	940	26	38	26	211200000000000000	ID
84094	0B	38	W	F	I	2350	35	51	29	211100030000000000	ID
84102	1D	25	B	F	P	750	23	36	23	212200000000000000	ID
84106	0B	25	W	F	X	1060	21	31	00	000000000000000000	CN
84107	0B	26	B	F	P	690	21	34	21	211000030000000000	MF
84108	0B	36	B	F	P	1310	28	39	31	111000000000000000	ID
84111	0B	36	B	M	P	2130	33	48	34	322100000000000000	ID
84113	9Y	00	B	F	X	00000	00	00	00	111100002000000000	CP
84129	1M	38	A	F	I	3180	32	49	36	132000000000000000	DW
84134	0B	22	B	M	P	820	25	35	23	011000000000000000	NO
84136	0B	22	B	M	P	530	19	30	20	100000000000000000	NO
84138	0B	38	W	F	I	3060	34	47	35	222210000000000000	NO
84141	8Y	00	W	M	X	22680	00	00	00	211100030020300000	CM
84144	1M	38	A	F	I	3540	42	49	36	211100000000000000	NO
84146	1D	34	W	F	P	1740	28	42	28	212200000000000000	MM
84151	0B	00	W	F	X	1540	24	37	18	111000000000000000	AC
84153	0B	32	L	M	P	1800	30	41	33	212000000001000000	ID
84154	1D	31	W	M	P	1210	26	38	28	211100030000000000	ID
84155	1D	25	W	M	P	200	20	32	21	112210000000000000	ID
84156	1D	36	L	M	P	2240	31	46	31	113300000002000000	ID
84162	0B	00	B	M	X	2050	31	51	31	312200000000000000	ID
84164	20D	37	A	F	I	2571	33	45	34	211100010000000000	NO
84166	10D	34	L	M	P	2580	32	48	34	212300030002000000	NO
84167	0B	00	W	M	X	3600	37	57	35	112110000000000000	ID
84169	24D	32	B	M	P	1170	23	34	28	111000000000000000	NO
84173	2D	23	W	F	P	570	21	28	23	211000000000000000	ID
84182	0B	24	W	M	P	·720	22	35	24	010000000000000000	ID
84205	1D	24	W	M	P	550	22	32	21	011100000000000000	CA
84206	0B	24	W	F	P	550	23	33	21	111000000000000000	MF
84207	4M	00	B	M	X	00000	00	00	00	321220000300030000	SD
84214	2D	34	W	F	P	1520	30	39	27	111100000000000000	MM
84215	9D	26	L	M	P	740	21	33	23	000000000000000000	RD
84221	1D	00	W	M	X	3810	39	53	35	111210000000000000	MF
84222	5M	00	W	F	X	6550	38	61	00	222000020300000000	HS
84223	0B	21	B	M	P	530	22	31	21	100000000000000000	CA
84227	0B	40	W	F	I	2440	33	50	31	111110000000000000	NO
84228	1M	00	B	M	X	4270	36	54	37	111100000000000000	SD
84229	1D	23	W	M	P	560	21	33	22	000000000000000000	NO
84230	1D	23	W	M	P	630	22	33	18	000000000000000000	NO
84237	0B	00	B	F	X	2250	33	49	31	112100000000000000	NO
84241	2D	00	L	F	X	00000	00	00	00	121200000020000000	DS
84247	12D	00	B	M	X	00000	00	00	00	112201000003000000	BI

Table 1. (Continued)

AUTOP	AGE	GA	R	S	B	WEIGH	CR	CH	HC	M12345XABCDEFGHIJK	MD
84252	0B	00	B	M	X	2945	00	51	33	11110100000000000	AP
84253	15Y	00	W	M	X	00000	00	00	00	11222100000000000	CF
84255	2M	00	L	F	X	4410	40	58	36	21110001000000000	SM
84257	10Y	00	W	F	X	00000	00	00	00	11111000000100000	TR
84262	0B	38	L	M	I	00000	00	00	00	21210001000000000	ID
84267	1D	23	L	F	P	650	21	35	22	11110000000100000	ID
84268	0B	23	W	F	P	540	21	31	22	21100000000000000	TR
84269	0B	23	W	F	P	650	21	33	23	21200000000000000	TR
84273	0B	37	L	F	I	00000	00	00	00	11111000000000000	ID
84274	0B	35	L	M	P	2280	00	49	32	11110000000000000	ID
84275	5M	00	W	M	X	5513	40	58	39	11100000000000000	BP
84282	0B	32	L	M	P	1440	29	40	29	11211000000000000	AP
84288	7M	00	B	M	X	00000	00	00	00	31220000003000000	CI
84289	0B	46	L	M	A	2740	31	49	00	21100000000000000	AC
84290	9Y	00	W	F	X	00000	00	00	00	11210000003001000	TR
84293	3D	38	L	F	I	2640	29	42	37	00000000000000000	DW
84309	1D	35	W	M	P	2480	31	42	00	11111000000100000	MM
84310	0B	38	A	F	I	3200	00	55	32	11110000000000000	NO
84311	0B	26	W	F	P	600	00	37	32	11100000000000000	ID
84315	1D	23	L	F	P	535	20	28	21	11100000000000000	ID
84323	1D	37	W	M	I	2230	22	50	00	11120000000000000	AC
84324	1D	28	B	M	P	1310	25	40	27	11210000000000000	RD
84329	0B	33	B	F	P	2300	00	47	34	11120000000010000	MF
84335	1D	24	B	M	P	540	20	30	21	00000000000000000	ID
84338	36M	00	W	M	X	00000	00	00	00	122110000101303000	PD
84341	6D	34	B	M	X	1300	28	41	28	11100000000000000	RD
84344	0B	28	B	M	X	830	24	36	25	10000000000000000	NO
84348	1D	26	L	M	X	790	34	35	24	11120000000000000	NO
84351	3M	00	B	M	P	3275	00	00	00	11220000000000000	BD
84361	15Y	00	A	M	X	00000	00	00	00	11110000000300000	TR
84367	2D	42	L	M	X	6260	43	62	47	31120103000000000	MD
84370	2D	38	W	F	X	3289	37	54	36	21230000000000000	CD
84373	0B	37	L	M	I	3250	33	50	35	21210000002000000	HY
35256	5M	00	W	M	X	00000	00	00	00	11111000000000000	TR
35264	9Y	00	W	M	X	00000	00	00	00	11121100000310000	TR
35295	36M	00	L	M	X	00000	00	00	00	11122000000020000	TR
35371	30M	00	B	F	X	00000	00	00	00	11110000000000000	TR
35451	4Y	00	B	M	X	00000	00	00	00	21200002000000000	TR
35604	15M	00	L	M	X	00000	00	77	00	222220030102000000	TR
35665	7Y	00	W	M	X	00000	00	00	00	11110100000100000	TR
35668	15M	00	W	M	X	15000	00	84	00	411111001000000000	TR
35669	5Y	00	W	M	X	21000	00	00	00	11220000002000000	TR
35703	10Y	00	W	M	X	30000	00	00	00	113220000020000000	TR
46157	6Y	00	W	M	X	48000	00	00	00	11221000003200000	TR
46187	36M	00	B	F	X	22000	00	99	00	11121000000000000	TR
84375	0B	36	B	M	I	2240	32	49	32	11222000000000000	NO
84380	10M	00	B	M	X	00000	00	79	00	11210000003000000	SC
84382	19Y	00	B	F	X	00000	00	00	00	111200003030320000	SB
84384	0B	41	B	M	P	2770	35	51	53	212210030003000000	AP

Table 2. Computer File 2

AUTOP	AGE	RS	TO	M12345X	ABCDEFG	Z
79014	-14	12	3	1110000	1110000	3
79055	156	32	6	2112000	1111000	4
79180	468	11	5	1111100	1111100	5
79183	12	21	7	1112110	1111110	6
79199	208	22	5	2111000	1111000	4
79218	478	32	6	1111110	1111110	6
79223	988	31	6	1111110	1111110	6
79251	884	11	6	1111110	1111110	6
79255	676	21	6	1122000	1111000	4
79326	-9	12	4	1120000	1110000	3
79327	-8	12	4	2110000	1110000	3
79328	-2	31	4	1111000	1111000	4
79330	676	22	5	1112000	1111000	4
79332	28	31	5	1112000	1111000	4
79333	-10	12	3	1200000	1100000	2
79342	-4	31	4	2110000	1110000	3
79348	6	22	5	1111100	1111100	5
79350	24	31	6	1211100	1111100	5
79355	-12	12	5	2120000	1110000	3
79366	1	12	8	1122200	1111100	5
79382	-5	22	3	1110000	1110000	3
79383	-10	21	5	2111000	1111000	4
79391	-7	22	5	1112000	1111000	4
79396	0	22	4	1111000	1111000	4
79401	-10	22	5	1112000	1111000	4
79405	832	31	8	1112210	1111110	6
80014	-13	21	3	1110000	1110000	3
80018	2	41	5	2111000	1111000	4
80045	260	11	5	1112000	1111000	4
80049	260	11	4	1111000	1111000	4
80055	144	32	6	2112000	1111000	4
80082	-2	31	6	1113000	1111000	4
80088	24	21	5	1112000	1111000	4
80089	208	21	7	2111200	1111100	5
80093	-11	11	4	1120000	1110000	3
80094	2	21	1	1000000	1000000	1
80098	-6	12	5	2111000	1111000	4
80099	-13	12	2	0011000	0011000	2
80100	-13	11	3	1110000	1110000	3
80101	36	11	6	1113000	1111000	4
80105	-10	12	4	1102000	1101000	3
80107	8	12	3	1110000	1110000	3
80108	-13	11	4	1111000	1111000	4
80112	-10	12	3	1011000	1011000	3
80113	-10	12	3	1110000	1110000	3
80114	-3	12	6	1112100	1111100	5
80116	-14	12	3	1110000	1110000	3
80118	-2	12	4	2110000	1110000	3
80119	-18	12	0	0000000	0000000	0
80124	6	11	7	1123000	1111000	4
80126	0	11	8	2123000	1111000	4
80128	-5	22	2	1100000	1100000	2
80147	-16	12	4	1111000	1111000	4
80149	-12	31	3	1110000	1110000	3

Table 2. (Continued)

AUTOP	AGE	RS	TO	M12345X	ABCDEFG	Z
80150	-6	21	6	1212000	1111000	4
80162	-10	11	4	1111000	1111000	4
80168	-10	12	2	1010000	1010000	2
80169	-1	31	5	1111100	1111100	5
80172	-3	32	8	2231000	1111000	4
80174	4	11	9	4212000	1111000	4
80175	2	11	8	1122200	1111100	5
80176	3	21	6	1112100	1111100	5
80177	8	22	7	1112200	1111100	5
80178	8	32	5	1112000	1111000	4
80181	2	21	5	1211000	1111000	4
80187	28	22	4	1111000	1111000	4
80192	-10	11	1	1000000	1000000	1
80199	8	11	5	1220000	1110000	3
80200	-11	21	5	2120000	1110000	3
80203	-13	12	5	1121000	1111000	4
80205	988	11	6	1111110	1111110	6
80206	-12	21	1	1000000	1000000	1
80213	-13	21	1	1000000	1000000	1
80215	4	21	7	2122000	1111000	4
80216	-16	22	0	0000000	0000000	0
80218	-6	32	1	1000000	1000000	1
80220	-10	11	4	1111000	1111000	4
80225	128	22	8	2122100	1111100	5
80227	16	31	8	1122200	1111100	5
80229	416	11	7	2112010	1111010	5
80234	2	12	7	1123000	1111000	4
80238	-15	22	1	1000000	1000000	1
80239	-15	22	2	1100000	1100000	2
80242	-4	31	5	1111100	1111100	5
80244	8	21	7	1122100	1111100	5
80247	0	31	5	1111100	1111100	5
80248	-1	32	4	1111000	1111000	4
80249	-1	32	3	1110000	1110000	3
80250	-2	11	5	1112000	1111000	4
80252	4	11	7	1122100	1111100	5
80254	-20	21	0	0000000	0000000	0
80260	-9	21	3	1110000	1110000	3
80267	-16	12	5	1121000	1111000	4
80270	6	12	7	3111100	1111100	5
80277	-4	11	5	1112000	1111000	4
80286	-14	22	6	1221000	1111000	4
80287	6	21	9	2222100	1111100	5
80289	-13	11	1	1000000	1000000	1
80293	-17	22	5	1121000	1111000	4
80299	3	21	2	1100000	1100000	2
80300	28	11	8	1123010	1111010	5
80306	-13	22	3	1110000	1110000	3
80307	-12	12	3	1110000	1110000	3
80309	0	21	7	1112200	1111110	5
80312	-12	11	4	1120000	1110000	3
80313	-5	12	5	1112000	1111000	4
80320	-10	11	11	1111000	1111000	4
80322	-8	11	7	2122000	1111000	4

Table 2. (Continued)

AUTOP	AGE	RS	TO	M12345X	ABCDEFG	Z
80324	-6	12	4	1111000	1111000	4
80325	-12	11	5	1112000	1111000	4
80332	88	11	11	4123100	1111100	5
80627	68	12	6	1111110	1111110	6
81002	36	21	6	1111110	1111110	6
81004	16	31	7	1112200	1111100	5
81007	-14	21	1	1000000	1000000	1
81008	-14	22	1	1000000	1000000	1
81010	3	31	4	1111000	1111000	4
81013	-14	22	2	1100000	1100000	2
81014	-5	22	4	2200000	1100000	2
81018	-5	12	5	1130000	1110000	3
81022	4	21	5	1112000	1111000	4
81024	208	12	5	2111000	1111000	4
81028	-13	22	4	2110000	1110000	3
81029	624	11	6	1112100	1111100	5
81032	16	11	7	4111000	1111000	4
81036	-2	12	5	1211000	1111000	4
81040	84	21	6	1111110	1111110	6
81046	-1	21	5	1121000	1111000	4
81057	84	21	6	1122000	1111000	4
81073	12	32	5	1112000	1111000	4
81084	-12	31	5	1111100	1111100	5
81091	-16	11	3	1110000	1110000	3
81100	3	31	4	1111000	1111000	4
81128	208	21	5	2111000	1111000	4
81133	520	31	7	1112110	1111110	6
81136	4	31	9	2222100	1111100	5
81114	0	11	10	3112201	1111101	6
81152	8	11	5	1112000	1111000	4
81172	936	11	6	1112100	1111100	5
81174	-1	11	5	1111100	1111100	5
81184	884	32	5	1111100	1111100	5
81186	988	12	5	1111100	1111100	5
81192	4	12	6	2111100	1111100	5
81200	416	22	6	1111110	1111110	6
81205	-4	12	5	1112000	1111000	4
81221	64	22	6	1122000	1111000	4
81235	8	12	4	1120000	1110000	3
81237	-3	12	7	1121200	1111100	5
81238	-11	11	1	1000000	1000000	1
81256	4	21	6	1122000	1111000	4
81269	-3	12	3	1110000	1110000	3
81283	-14	22	2	1100000	1100000	2
81285	64	21	8	1113110	1111110	6
81287	780	21	6	1111110	1111110	6
81289	16	32	10	1113310	1111110	6
81298	3	11	9	1112400	1111100	5
81302	208	12	6	1111110	1111110	6
81323	208	22	9	1122210	1111110	6
81340	76	11	4	1111000	1111000	4
81345	12	12	6	2111100	1111100	5
82004	936	31	4	1111000	1111000	4
82008	936	41	5	1111100	1111100	5

Table 2. (Continued)

AUTOP	AGE	RS	TO	M12345X	ABCDEFG	Z
82015	96	12	6	1121100	1111100	5
82027	208	11	5	1111100	1111100	5
82039	-4	32	5	1111100	1111100	5
82043	4	32	6	2111100	1111100	5
82045	-11	31	5	1111100	1111100	5
82060	-10	21	4	1110010	1110010	4
82062	676	11	5	1111010	1111010	5
82065	1	11	3	1110000	1110000	3
82069	728	31	5	1111100	1111100	5
82073	-11	32	4	1111000	1111000	4
82076	0	21	7	1112200	1111100	5
82084	728	32	5	1111100	1111100	5
82085	-6	21	6	1122000	1111000	4
82087	832	11	5	1111100	1111100	5
82096	780	32	6	1111110	1111110	6
82103	32	11	7	1112200	1111100	5
82114	728	11	6	1111110	1111110	6
82118	36	12	3	1110000	1110000	3
82125	8	21	6	1113000	1111000	4
82129	96	22	9	3112200	1111100	5
82135	96	12	9	2322000	1111000	4
82136	4	22	12	1461000	1111000	4
82139	-2	32	3	1110000	1110000	3
82140	144	11	7	2111110	1111110	6
82149	-11	11	3	1110000	1110000	3
82150	144	11	8	1132100	1111100	5
82159	0	31	4	1111000	1111000	4
82169	40	21	4	1111000	1111000	4
82181	4	11	13	4133200	1111100	5
82188	832	32	4	1111000	1111000	4
82189	96	12	4	1111000	1111000	4
82193	0	21	3	1110000	1110000	3
82210	-7	22	3	1110000	1110000	3
82211	936	31	6	1111110	1111110	6
82224	40	21	8	1112210	1111110	6
82228	4	21	8	1122200	1111100	5
82234	3	12	6	1112100	1111100	5
82236	-4	11	6	1311000	1111000	4
82245	-10	31	6	1111200	1111100	5
82248	0	31	5	1112000	1111000	4
82257	68	12	9	1123200	1111100	5
82258	68	12	5	2111000	1111000	4
82260	32	32	7	1112110	1111110	6
82270	20	32	5	2111000	1111000	4
82272	-6	11	3	1110000	1110000	3
82273	-4	21	3	1110000	1110000	3
82274	572	12	4	1110100	1110100	4
82275	-5	22	2	1010000	1010000	2
82281	-4	12	5	1121000	1111000	4
82283	208	31	10	4122100	1111100	5
82286	32	21	6	1112010	1111010	5
82287	-1	11	5	1111100	1111100	5
82295	-12	12	3	2100000	1100000	2
82297	1	11	6	1112100	1111100	5

Table 2. (Continued)

AUTOP	AGE	RS	TO	M12345X	ABCDEFG	Z
82298	-4	11	5	1111100	1111100	5
82303	-10	21	6	2121000	1111000	4
82304	364	22	3	1110000	1110000	3
82309	5	32	5	1112000	1111000	4
82313	208	22	5	1111100	1111100	5
82324	20	11	8	1212200	1111100	5
82325	20	12	5	1112000	1111000	4
82326	-11	22	5	1112000	1111000	4
82331	144	11	9	2221200	1111100	5
83015	1	31	7	2112100	1111100	5
83016	12	32	4	1111000	1111000	4
83021	-3	12	5	1112000	1111000	4
83025	2	11	8	1142000	1111000	4
83029	2	21	4	1110100	1110100	4
83030	-2	11	8	2222000	1111000	4
83031	20	22	6	3111000	1111000	4
83032	988	31	5	1111010	1111010	5
83034	-2	12	0	0000000	0000000	0
83035	44	32	12	3111330	1111110	6
83041	936	22	5	1111100	1111100	5
83045	-15	21	1	1000000	1000000	1
83054	572	12	5	1111100	1111100	5
83059	-15	22	3	1110000	1110000	3
83067	48	12	8	3112100	1111100	5
83072	-15	31	3	1110000	1110000	3
83075	-8	11	7	1312000	1111000	4
83079	-8	21	2	2000000	1000000	1
83087	-15	12	4	1120000	1110000	3
83088	-9	11	5	1220000	1110000	3
83089	-13	21	5	2111000	1110000	3
83098	-14	11	1	1000000	1000000	1
83099	-14	41	2	1100000	1100000	2
83100	2	12	6	1212000	1111000	4
83102	28	22	6	3111000	1111000	4
83104	-5	22	6	1122000	1111000	4
83106	4	11	3	1110000	1110000	3
83109	3	11	10	2123200	1111100	5
83111	-14	21	0	0000000	0000000	0
83113	-14	11	6	2111100	1111100	5
83116	728	21	4	1111000	1111000	4
83119	-6	11	7	1122100	1111100	5
83121	4	22	5	3110000	1110000	3
83122	-18	21	4	1120000	1110000	3
83125	2	31	5	1211000	1111000	4
83128	-9	31	4	1111000	1111000	4
83129	-13	12	2	1100000	1100000	2
83131	-18	22	0	0000000	0000000	0
83132	4	32	6	3111000	1111000	4
83138	-14	11	1	0100000	0100000	1
83139	-14	11	0	0000000	0000000	0
83140	4	11	7	2221000	1111000	4
83145	64	32	7	3111010	1111010	5
83146	-13	12	3	1110000	1110000	3
83149	144	12	5	1112000	1111000	4

Table 2. (Continued)

AUTOP	AGE	RS	TO	M12345X	ABCDEFG	Z
83151	-6	11	8	2122100	1111100	5
83155	-1	22	4	1111000	1111000	4
83162	4	11	10	2121310	1111110	6
83164	-14	12	5	1111100	1111100	5
83165	-13	11	3	1110000	1110000	3
83168	68	12	5	1111100	1111100	5
83170	312	11	8	1112210	1111110	6
83171	832	12	4	1111000	1111000	4
83172	2	22	8	1122200	1111100	5
83173	120	21	7	1222000	1111000	4
83175	-13	21	1	1000000	1000000	1
83176	-9	42	5	1112000	1111000	4
83178	40	21	10	2122210	1111110	6
83183	-14	11	1	1000000	1000000	1
83184	832	11	4	1111000	1111000	4
83185	120	12	11	4122110	1111110	6
83188	1	21	4	1111000	1111000	4
83189	-10	22	1	1000000	1000000	1
83190	8	31	7	1121200	1111100	5
83194	-1	31	5	1111100	1111100	5
83197	-4	11	4	1111000	1111000	4
83199	120	22	4	1111000	1111000	4
83202	0	12	6	1221000	1111000	4
83203	-8	11	6	1212000	1111000	4
83205	8	32	4	2110000	1110000	3
83208	-9	11	5	1111100	1111100	5
83210	-10	11	5	1112000	1111000	4
83211	0	12	12	3232200	1111100	5
83213	-16	12	3	1110000	1110000	3
83214	-8	11	3	1110000	1110000	3
83220	120	12	5	1121000	1111000	4
83231	832	11	6	1111110	1111110	6
83233	8	12	7	3121000	1111000	4
83234	4	21	5	2111000	1111000	4
83236	-14	11	4	2110000	1110000	3
83237	-14	12	2	1100000	1100000	2
83240	-8	22	4	4000000	1000000	1
83241	-12	32	3	1110000	1110000	3
83243	52	12	8	1312100	1111100	5
83245	-11	11	6	1122000	1111000	4
83246	-12	12	0	0000000	0000000	0
83247	4	21	4	1111000	1111000	4
83248	-14	12	0	0000000	0000000	0
83253	-16	11	2	1100000	1100000	2
83254	-13	12	3	1110000	1110000	3
83259	-15	31	3	1110000	1110000	3
83263	12	22	3	1110000	1110000	3
83264	10	22	5	1121000	1111000	4
83266	5	12	4	1111000	1111000	4
83269	20	12	5	1111100	1111100	5
83272	36	12	4	1120000	1110000	3
83274	96	22	9	1122210	1111110	6
83280	-3	22	7	1222000	1111000	4
83282	-1	12	7	2122000	1111000	4

Table 2. (Continued)

AUTOP	AGE	RS	TO	M12345X	ABCDEFG	Z
83287	3	22	4	2110000	1110000	3
~~83291~~	8	11	11	~~2213210~~	1111110	6
83294	12	12	4	1111000	1111000	4
83296	4	32	5	1112000	1111000	4
83297	-11	32	4	1111000	1111000	4
83298	-13	12	5	2120000	1110000	3
83303	8	22	9	2122200	1111100	5
83304	-4	22	3	1110000	1110000	3
83317	-2	32	5	1111100	1111100	5
83318	364	12	4	1111000	1111000	4
83322	-8	11	3	1110000	1110000	3
83323	-2	12	6	1212000	1111000	4
83325	12	31	8	2122100	1111100	5
83327	8	12	6	1122000	1111000	4
83328	88	11	7	1112110	1111110	6
83332	-11	11	5	1220000	1111000	4
83333	28	22	4	1111000	1111000	4
83335	6	11	7	1122100	1111100	5
83337	-3	31	5	1112000	1111000	4
83338	-2	11	3	1110000	1110000	3
83339	4	12	0	0000000	0000000	0
83340	0	12	5	1112000	1111000	4
83343	4	11	5	2111000	1111000	4
83345	-16	11	3	2100000	1100000	2
83356	2	11	9	3122100	1111100	5
83357	-7	11	2	1100000	1100000	2
83358	728	12	4	1111000	1111000	4
83359	8	31	5	1112000	1111000	4
83363	8	12	3	3000000	1000000	1
83368	1	21	4	1111000	1111000	4
83370	8	11	10	2332000	1111000	4
83371	4	32	2	1100000	1100000	2
83377	-16	11	1	1000000	1000000	1
83382	-4	32	3	1110000	1110000	3
83386	208	11	6	1111110	1111110	6
84002	8	12	9	4221000	1111000	4
84004	4	12	4	1111000	1111000	4
84005	4	31	6	1112100	1111100	5
84006	-11	22	3	1110000	1110000	3
84011	-4	31	5	2111000	1111000	4
84019	16	11	6	1122000	1111000	4
84022	1	21	8	1222100	1111100	5
84023	4	31	8	3122000	1111000	4
84032	-11	12	4	1111000	1111000	4
84037	12	12	4	1111000	1111000	4
84040	32	11	4	1011010	1011010	4
84041	-4	11	9	3222000	1111000	4
84042	-1	31	9	3123000	1111000	4
84046	-3	12	5	1112000	1111000	4
84048	12	31	6	2211000	1111000	4
84050	-16	12	4	1120000	1110000	3
84051	3	12	6	2111100	1111100	5
84058	40	12	4	1111000	1111000	4
84059	4	31	10	6220000	1110000	3

Table 2. (Continued)

AUTOP	AGE	RS	TO	M12345X	ABCDEFG	Z
84061	-4	31	5	1112000	1111000	4
84063	4	11	9	2132100	1111100	5
84067	88	12	7	3112000	1111000	4
84068	2	11	5	1111100	1111100	5
84072	96	12	4	1111000	1111000	4
84074	450	22	7	1222000	1111000	4
84076	1	12	5	1112000	1111000	4
84077	3	21	9	1123200	1111100	5
84084	-6	12	6	2121000	1111000	4
84088	312	31	7	1112200	1111100	5
84090	-5	22	6	2112000	1111000	4
84094	0	12	5	2111000	1111000	4
84102	-13	22	7	2122000	1111000	4
84106	-13	12	0	0000000	0000000	0
84107	-12	22	4	2110000	1110000	3
84108	-2	22	3	1110000	1110000	3
84111	-2	21	8	3221000	1111000	4
84113	468	22	4	1111000	1111000	4
84129	0	42	6	1320000	1110000	3
84134	-16	21	2	0110000	0110000	2
84136	-16	21	1	1000000	1000000	1
84138	0	12	9	2222100	1111100	5
84141	416	11	5	2111000	1111000	4
84144	4	42	5	2111000	1111000	4
84146	-4	12	7	2122000	1111000	4
84151	4	12	3	1110000	1110000	3
84153	-6	31	5	2120000	1110000	3
84154	-7	11	5	2111000	1111000	4
84155	-13	11	7	1122100	1111100	5
84156	-2	31	8	1133000	1111000	4
84162	4	21	8	3122000	1111000	4
84164	2	42	5	2111000	1111000	4
84166	-3	31	8	2123000	1111000	4
84167	-10	11	6	1121100	1111100	5
84169	-3	21	3	1110000	1110000	3
84173	-15	12	4	2110000	1110000	3
84182	-14	11	1	0100000	0100000	1
84205	-14	11	3	0111000	0111000	3
84206	-14	12	3	1110000	1110000	3
84207	16	21	10	3212200	1111100	5
84214	-4	12	4	1111000	1111000	4
84215	-11	31	0	0000000	0000000	0
84221	4	11	6	1112100	1111100	5
84222	20	12	6	2220000	1110000	3
84223	-17	21	1	1000000	1000000	1
84227	2	12	5	1111100	1111100	5
84228	4	21	4	1111000	1111000	4
84229	-15	11	0	0000000	0000000	0
84230	-15	11	0	0000000	0000000	0
84237	4	22	5	1121000	1111000	4
84241	4	32	6	1212000	1111000	4
84247	2	21	6	1122000	1111000	4
84252	4	21	4	1111000	1111000	4
84253	780	11	9	1122210	1111110	6

Table 2. (Continued)

AUTOP	AGE	RS	TO	M12345X	ABCDEFG	Z
84255	8	32	5	2111000	1111000	4
84257	520	12	5	1111100	1111100	5
84262	0	31	6	2121000	1111000	4
84267	-15	32	4	1111000	1111000	4
84268	-15	12	4	2110000	1110000	3
84269	-15	12	5	2120000	1110000	3
84273	9	32	5	1111100	1111100	5
84274	-8	31	4	1111000	1111000	4
84275	20	11	3	1110000	1110000	3
84282	-6	31	6	1121100	1111100	5
84288	28	21	8	3122000	1111000	4
84289	8	31	4	2110000	1110000	4
84290	468	12	5	1121000	1111000	4
84293	0	32	0	0000000	0000000	0
84309	-3	11	5	1111100	1111100	5
84310	0	42	4	1111000	1111000	4
84311	-12	12	3	1110000	1110000	3
84315	-15	42	3	1110000	1110000	3
84323	-1	11	5	1112000	1111000	4
84324	-10	21	5	1121000	1111000	4
84329	-5	21	5	1112000	1111000	4
84335	-14	21	0	0000000	0000000	0
84338	144	11	7	1221100	1111100	5
84341	-3	21	3	1110000	1110000	3
84344	-10	21	1	1000000	1000000	1
84348	-12	31	5	1112000	1111000	4
84351	12	21	6	1122000	1111000	4
84361	780	41	4	1111000	1111000	4
84367	4	31	7	3112000	1111000	4
84370	0	12	8	2123000	1111000	4
84373	1	31	6	2121000	1111000	4
35256	20	11	5	1111100	1111100	5
35264	468	11	7	1112110	1111110	6
35295	144	31	7	1112200	1111100	5
35371	120	12	4	1111000	1111000	4
35451	208	21	5	2120000	1110000	3
35604	60	31	10	2222200	1111100	5
35665	364	11	5	1111010	1111010	5
35668	60	11	9	4111110	1111110	6
35669	260	11	6	1122000	1111000	4
35703	520	11	9	1132200	1111100	5
46157	312	11	7	1122100	1111100	5
46187	144	21	6	1112100	1111100	5
84375	-2	21	8	1122200	1111100	5
84380	40	21	5	1121000	1111000	4
84382	988	21	5	1112000	1111000	4
84384	3	21	8	2122100	1111000	4

Table 3. Diseases or Conditions Contributing to Death Listed by Code and Non- Abbreviated Form

GD	Gauchers disease
DN	Desmoplastic cerebral neurobastoma
OD	Olivopontocerebellar degeneration
WD	Werding-Hoffmann's disease
SS	Subglottic stenosis
GA	Gastroenteritis
LB	Laryngotracheobrochitis
DS	Down syndrome
PH	Pulmonary hypertension
BP	Bronchopneumonia
BD	Bronchopulmonary dysplasia
HY	Hyrocephalic
DU	Double ureters
TR	Trauma, automobile crash, poisoning, asphixia, gunshot
BC	Bacteremia
SD	Sudden infant death syndrome
TS	Turners syndrome
MG	Meningococcossis
PI	Placental insuffiency or placental infarction
NB	Neuroblastoma
CD	Congenital heart disease
NO	Unknown
TA	Theraputic abortion
CP	Cerebral palsy
CI	Complications of immunity
DH	Severe dehydration
SM	Severe malnutrition
CT	Congenital tyrosemmia
GR	Growth retardation
SC	Sickle-cell anemia
SB	Spinal bifida
NC	neurocutaneous melanoma syndrome
BH	Brain hemmorage
HD	Hinschspring's disease
CN	Cystopyelonephritis
GS	gastroschisis
NS	nephrotic syndrome
MM	Multiple congenital malformations
PD	Glucose 6-PDH diffiency
CS	Congenital syphilis
CM	Congenital megalencephaly
BI	Blood incompatibility; clotting problems
DW	Dwarfism; thanatrophic, pituitary, achordroplastic
PM	Psychogenic malnutrition
DD	Duchennes dystrophy
LB	Lymphoblastic leukemia
SP	Septicemia
JP	Juvenile papillomatosis
PW	Prader-Willi syndrome
NE	Necrotizing enterocolitis
PC	Portal cirrhosis
JB	Jansky-Bielschousky syndrome
RS	Reyes syndrome
MG	Meningococcosis
CF	Cystic fibrosis
LL	Lymphocytic leukemia
MS	Maternal syphilis
ID	Immature development
MD	Maternal diabetes
CH	Congenital diaphramatic hernia
CA	Acute chorioamnionitis
AC	Anencephaly
CE	Cerebral endema
KD	Kidney dysplasia
RD	Respiratory distress syndrome
JD	Juvenile diabetes
VS	Vater syndrome
PS	Post-mature syndrome
HT	Histiocytosis
ML	Myebgenus leukemia
NB	Nesidoblastosis
IA	Intrauterine anoxia
MH	Maternal hypertension
PG	Pulmonary hypertension
MY	Myocarditis
HM	Hyaline membrane disease
LE	Lupus erythematosus
MF	Maternal failure; knot in umbilical cord, traumatic delivery
MA	Meconium aspiration
ES	Ewings sarcoma
HP	Hyperostosis
AP	Abruptio placenta

Table 4. The Possible Ossification Patterns Observed in Fetus and Newborns Gestational Ages 18 to 38 Weeks

Total # of centers	M	1	2	3	4	5	X	Percent of Occurrence
0	0	0	0	0	0	0	0	5
2	0	0	1	1	0	0	0	*
1	0	1	0	0	0	0	0	*
2	0	1	1	0	0	0	0	*
3	0.	1	1	1	0	0	0	*
1	0	0	0	0	0	0	0	7
2	1	0	1	0	0	0	0	*
3	1	0	1	1	0	0	0	*
2	1	1	0	0	0	0	0	3
4	1	1	0	2	0	0	0	*
3	1	1	1	0	0	0	0	25
4	1	1	1	0	1	0	0	*
4	1	1	1	1	0	0	0	10
5	1	1	1	1	1	0	0	*
7	1	1	1	1	3	0	0	*
6	1	1	1	1	2	0	0	*
5	1	1	1	2	0	0	0	11
6	1	1	1	2	1	0	0	1
7	1	1	1	2	2	0	0	*
8	1	1	1	2	3	0	0	*
10	1	1	1	2	5	0	0	*
6	1	1	1	3	0	0	0	*
4	1	1	2	0	0	0	0	1
5	1	1	2	1	0	0	0	2
7	1	1	2	1	2	0	0	*
6	1	1	2	2	0	0	0	1
7	1	1	2	2	1	0	0	1
8	1	1	2	2	2	0	0	1
9	1	1	2	2	3	0	0	*
7	1	1	2	3	0	0	0	*
9	1	1	2	3	2	0	0	*
8	1	1	3	3	0	0	0	*
8	1	1	4	2	0	0	0	*
3	1	2	0	0	0	0	0	*
5	1	2	1	1	0	0	0	1
6	1	2	1	2	0	0	0	2
5	1	2	2	0	0	0	0	1
6	1	2	2	1	0	0	0	*
7	1	2	2	2	0	0	0	*
9	1	2	2	2	2	0	0	*
6	1	3	1	1	0	0	0	*
7	1	3	1	2	0	0	0	*
6	1	3	2	0	0	0	0	*
2	2	0	0	0	0	0	0	*
3	2	1	0	0	0	0	0	*
4	2	1	1	0	0	0	0	3
5	2	1	1	0	1	0	0	*
3	2	1	1	1	0	0	0	3
4	2	1	1	1	1	0	0	1
4	2	1	1	2	0	0	0	*
6	2	1	1	2	2	0	0	*
5	2	1	2	0	0	0	0	1
6	2	1	2	1	0	0	0	1
7	2	1	2	2	0	0	0	1
8	2	1	2	2	1	0	0	*
8	2	1	2	3	0	0	0	1
10	2	1	2	3	2	0	0	*
4	2	2	0	0	0	0	0	*
7	2	2	2	1	0	0	0	*
8	2	2	2	2	0	0	0	*
9	2	2	2	2	1	0	0	*
10	2	2	2	2	2	0	0	*
8	2	2	3	1	0	0	0	*
7	3	1	1	1	1	0	0	*
8	3	1	1	2	1	0	0	*
10	3	1	1	2	3	0	0	*
9	3	1	2	3	0	0	0	*
8	3	2	2	1	0	0	0	*
6	3	2	2	2	0	0	0	*
12	3	2	3	2	2	0	0	*
4	4	0	0	0	0	0	0	*
13	4	1	3	3	2	0	0	*

Table 5. Possible Number of Ossification Centers in each Segment of the Sternum and the Percent of Occurrence as Observed in Fetus and Newborns Gestational Ages 18 to 38 Weeks

Manubrium		sternebra 1		sternebra 2		sternebra 3		sternebra 4	
#	%	#	%	#	%	#	%	#	%
0	2	0	1	0	15	0	41	0	85
1	76	1	84	1	58	1	25	1	8
2	19	2	14	2	25	2	25	2	5
3	2	3	1	3	2	3	9	3	2
4	*			4	*			4	*

Table 6. The 63 Possible Ossification Patterns Observed in Infants Ages 1 to 36 Months

Total # of Centers	M	1	2	3	4	5	X	Percent of Occurrence
4	1	0	1	1	0	1	0	*
3	1	1	1	0	0	0	0	3
4	1	1	1	1	0	0	0	14
5	1	1	1	1	1	0	0	2
6	1	1	1	1	1	1	0	2
5	1	1	1	2	0	0	0	7
6	1	1	1	2	0	1	0	4
6	1	1	1	2	1	0	0	*
7	1	1	1	2	1	1	0	2
7	1	1	1	2	2	0	0	3
8	1	1	1	2	2	1	0	*
6	1	1	1	3	0	0	0	2
8	1	1	1	3	1	1	0	*
10	1	1	1	3	3	1	0	*
4	1	1	2	0	0	0	0	2
5	1	1	2	1	0	0	0	2
6	1	1	2	1	1	0	0	*
7	1	1	2	1	2	0	0	*
6	1	1	2	2	0	0	0	4
7	1	1	2	2	1	0	0	2
8	1	1	2	2	2	0	0	*
9	1	1	2	2	2	1	0	*
8	1	1	2	3	0	1	0	*
9	1	1	2	3	2	0	0	2
8	1	1	3	2	1	0	0	*
6	1	2	1	1	1	0	0	*
8	1	2	1	2	2	0	0	*
7	1	2	2	1	1	0	0	*
7	1	2	2	2	0	0	3	*
8	1	3	1	2	1	0	0	*
6	1	3	2	0	0	0	0	*
12	1	4	6	1	0	0	0	*
4	2	1	1	0	0	0	0	*
5	2	1	1	1	0	0	0	4
7	2	1	1	1	1	1	0	*
10	2	1	2	1	3	1	0	*
7	2	1	2	2	0	0	0	2
8	2	1	2	2	1	0	0	2
9	2	1	2	2	2	0	0	*
10	2	1	2	2	2	1	0	*
6	2	2	1	1	0	0	0	*
11	2	2	1	3	2	1	0	*
6	2	2	2	0	0	0	0	*
9	2	2	2	1	2	0	0	*
10	2	2	2	2	2	0	0	*
9	2	3	2	2	0	0	0	*
10	2	3	3	2	0	0	0	*
3	3	0	0	0	0	0	0	*
6	3	1	1	1	0	0	0	2
7	3	1	1	1	0	1	0	*
12	3	1	1	1	3	3	0	*
7	3	1	1	2	0	0	0	*
8	3	1	1	2	1	0	0	*
9	3	1	1	2	2	0	0	2
7	3	1	2	1	0	0	0	*
8	3	1	2	2	0	0	0	2
10	3	2	1	2	2	0	0	*
7	4	1	1	1	1	0	0	*
9	4	1	1	1	1	1	0	*
11	4	1	2	2	1	1	0	*
11	4	1	2	3	1	0	0	*
9	4	2	2	1	0	0	0	*
10	6	2	2	0	0	0	0	*

Table 7. Possible Number of Ossification Centers in each Segment of the Sternum and the Percent of Occurrence as Observed in Infants Ages 1 to 36 Months

Manubrium		sternebra 1		sternebra 2		sternebra 3		sternebra 4	
#	%	#	%	#	%	#	%	#	%
0	0	0	*	0	*	0	9	0	60
1	68	1	84	1	62	1	41	1	22
2	17	2	11	2	35	2	42	2	15
3	10	3	3	3	1	3	8	3	3
4	4	4	*						
6	*			6	*				

sternebra 5	
#	%
0	82
1	17

Table 8. The 13 Possible Ossification Patterns and their Percentage of Occurrence in Children 4 to 6 Years of Age

Total # of centers	M	1	2	3	4	5	X	Percent of Occurrence
4	1	1	1	1	0	0	0	6
5	1	1	1	1	1	0	0	11
6	1	1	1	1	1	1	0	11
5	1	1	1	2	0	0	0	6
7	1	1	1	2	2	0	0	6
8	1	1	1	2	2	1	0	6
6	1	1	2	2	0	0	0	6
7	1	1	2	2	1	0	0	6
9	1	1	2	2	2	1	0	6
5	2	1	1	1	0	0	0	17
7	2	1	1	1	2	0	0	6
5	2	1	2	0	0	0	0	6

Table 9. Possible Number of Ossification Centers in each Segment of the Sternum and Percent of Occurrence as Observed in Children 4 to 6 Years of Age

Manubrium		sternebra 1		sternebra 2		sternebra 3		sternebra 4	
#	%	#	%	#	%	#	%	#	%
0	0	0	0	0	0	0	6	0	41
1	65	1	100	1	71	1	53	1	35
2	29			2	29	2	41	2	24
4	6								

sternebra 5	
#	%
0	76
1	24

Table 10. The 8 Possible Ossification Patterns and their Percentage of Occurrence in Children 7 to 9 Years of Age

Total # of Centers	M	1	2	3	4	5	X	Percent of Occurrence
3	1	1	1	0	0	0	0	10
4	1	1	1	1	0	0	0	20
5	1	1	1	1	1	0	0	10
6	1	1	1	1	1	1	0	20
7	1	1	1	2	1	1	0	10
5	2	1	1	2	0	1	0	10
7	2	1	1	2	0	1	0	10
5	1	1	1	1	1	0	1	10

Table 11. Possible Number of Ossification Centers in each Segment of the Sternum and their Frequency of Occurrence in Children 7 to 9 Years of Age

Manubrium #	Manubrium %	sternebra 1 #	sternebra 1 %	sternebra 2 #	sternebra 2 %	sternebra 3 #	sternebra 3 %	sternebra 4 #	sternebra 4 %
0	0	0	0	0	0	0	17	0	67
1	100	1	100	1	67	1	67	1	33
						3	33		
						4	17		

sternebra 5 #	sternebra 5 %
0	0

Table 12. The 4 Possible Ossification Patterns and their Percentage of Occurrence in Pre-Adolescents 10 to 12 years

Total # of Centers	M	1	2	3	4	5	X	Percent of Occurrence
5	1	1	1	1	0	0	1	33
5	1	1	1	1	1	0	0	33
6	1	1	3	0	0	0	0	17
9	1	1	3	4	0	0	0	17

Table 13. Possible Number of Ossification Centers in each Segment of the Sternum and the Frequency of Occurrence in Pre-Adolescents 10 to 12 Years

Manubrium #	Manubrium %	sternebra 1 #	sternebra 1 %	sternebra 2 #	sternebra 2 %	sternebra 3 #	sternebra 3 %	sternebra 4 #	sternebra 4 %
0	0	0	0	0	0	0	17	0	67
1	100	1	100	1	67	1	67	1	33
						3	33		
						4	17		

sternebra 5 #	sternebra 5 %
0	0

Table 14. The 6 Possible Ossification Patterns and their Percentage of Occurrence in Adolescents 13 to 15 Years

Total # of Centers	M	1	2	3	4	5	X	Percent of Occurrence
4	1	1	1	1	0	0	0	50
5	1	1	1	1	1	0	0	26
6	1	1	1	1	1	1	0	8
5	1	1	1	1	0	0	1	8
9	1	1	2	2	2	1	0	8
6	1	1	2	2	0	0	0	8

Table 15. Possible Number of Ossification Centers in each Segment of the Sternum and the Frequency of Occurrence in Adolescents 13 to 15 Years

Manubrium		sternebra 1		sternebra 2		sternebra 3		sternebra 4	
#	%	#	%	#	%	#	%	#	%
0	0	0	0	0	0	0	0	0	58
1	100	1	100	1	83	1	83	1	33
				2	17	2	17	2	8

sternebra 5	
#	%
0	83
1	17

Table 16. The 7 Possible Ossification Patterns and their Percentage of Occurrence in Late-Adolescents 16 to 19 Years

Total # of Centers	M	1	2	3	4	5	X	Percent of Occurrence
4	1	1	1	1	0	0	0	27
5	1	1	1	1	0	1	0	5
5	1	1	1	1	1	0	0	27
6	1	1	1	1	1	1	0	27
5	1	1	1	2	0	0	0	5
6	1	1	1	2	1	0	0	5
3	1	1	1	0	0	0	0	5

Table 17. Possible Number of Ossification Centers in each Segment of the Sternum and the Frequency of Occurrence in Late-Adolescents 16 to 19 Years

Manubrium		sternebra 1		sternebra 2		sternebra 3		sternebra 4	
#	%	#	%	#	%	#	%	#	%
0	0	0	0	0	0	0	5	0	42
1	100	1	100	1	100	1	84	1	58
						2	11		

sternebra 5	
#	%
0	68
1	32

Table 18. Results of Sort Procedure: AGE vs TO

Age in Weeks	Mean	Standard Deviation	Variance	Observations	Minimum Value	Maximum Value
18g	2.419	1.688	2.851	31	0	5
28g	3.656	1.988	3.953	125	0	11
38g	5.696	2.270	5.157	145	0	13
10	5.871	1.949	3.798	39	3	11
20	6.375	1.892	3.583	16	3	10
30	5.900	1.595	2.544	10	4	8
40	6.200	2.936	8.622	10	3	12
50	8.000	.0	.0	2	8	8
60	8.000	1.581	2.500	5	6	10
70	6.250	1.892	3.583	4	5	9
80	5.333	1.154	1.333	3	4	6
90	8.333	2.309	5.333	3	7	11
100	6.833	2.483	6.166	6	4	9
120	6.200	2.949	8.700	5	5	11
130	8.000	.0	.0	1	8	8
140	6.875	1.246	1.553	8	5	9

Table 19. Results of Sort Procedure: AGE vs Z

Age in Weeks	Mean	Standard Deviation	Variance	Observations	Minimum Value	Maximum Value
18g	2.096	1.374	1.890	31	0	4
28g	2.936	1.348	1.818	125	0	5
38g	4.041	.963	.928	145	0	6
10	4.179	.913	.835	39	1	6
20	4.437	.81	.662	16	3	6
30	4.500	.707	.550	10	4	6
40	4.600	1.264	1.600	10	3	6
50	5.000	.0	.0	2	5	5
60	5.200	.836	.700	5	4	6
70	5.000	.816	.666	4	4	6
80	4.666	1.154	1.333	3	4	6
90	5.000	1.000	1.000	3	4	6
100	4.666	.816	.666	6	4	6
120	4.400	.894	.800	5	4	6
130	5.000	.0	.0	1	5	5
140	4.875	.640	.410	8	4	6

Table 20. Results of Sort Procedure: S vs AGE

Sex	Age in Weeks	Mean	Standard Deviation	Variance	Observations	Minimum Value	Maximum Value
Male	18g	1.714	1.325	1.758	14	0	4
Female	18g	3,000	1.767	3.125	17	0	5
Male	28g	3.823	2.265	5.132	68	0	11
Female	28g	3.456	1.593	2.538	57	0	7
Male	38	6.034	2.207	4.870	87	1	13
Female	38	5.189	2.290	5.244	58	0	12
Male	10	6.875	1.892	3.583	16	4	11
Female	10	5.173	1.696	2.877	23	3	9
Male	20	6.500	1.957	3.833	10	3	10
Female	20	6.166	1.940	3.766	6	5	10
Male	30	6.333	1.632	2.666	6	4	8
Female	30	5.250	1.500	2.250	4	4	7
Male	40	6.500	2.167	4.700	6	4	10
Female	40	5.750	4.193	17.583	4	3	12
Male	50	8.000	.0	.0	2	8	8
Male	60	9.000	1.000	1.000	3	8	10
Female	60	6.500	.707	.500	2	6	7
Female	70	6.250	1.892	3.583	4	5	9
Male	80	5.333	1.154	1.333	3	4	6
Male	90	9.000	2.828	8.000	2	7	11
Female	90	7.000	.0	.0	1	7	7
Female	100	6.833	2.483	6.166	6	4	9
Male	120	7.000	.0	.0	1	7	7
Female	120	6.000	3.366	11.333	4	4	11
Female	130	8.000	.0	.0	1	8	8
Male	140	7.333	1.032	1.066	6	6	9
Female	140	5.500	.707	.500	2	5	6

Table 21. Results of Sort Procedure: Z vs AGE

Sex	Age in Weeks	Mean	Standard Deviation	Variance	Observations	Minimum Value	Maximum Value
Male	18g	1.571	1.157	1.340	14	0	3
Female	18g	2.529	1.419	2.01	17	0	4
Male	28g	3.029	1.505	2.267	68	0	5
Female	28g	2.824	1.135	1.290	57	0	5
Male	38g	4.206	.794	.631	87	1	6
Female	38g	3.793	1.135	1.289	58	0	5
Male	10	4.500	.816	.666	16	3	6
Female	10	3.95	.928	.861	23	1	5
Male	20	4.500	.707	.500	10	3	5
Female	20	4.333	1.032	1.066	6	3	6
Male	30	4.500	.547	.300	6	4	5
Female	30	4.500	1.000	1.000	4	4	6
Male	40	5.000	1.095	1.200	6	4	6
Female	40	4.000	1.414	2.000	4	3	6
Female	50	5.000	.0	.0	2	5	5
Male	60	5.666	.577	.333	3	5	6
Female	60	4.500	.707	.500	2	4	5
Female	70	5.000	.816	.666	4	4	6
Male	80	4.666	1.154	1.333	3	4	6
Male	90	5.500	.707	.500	2	5	6
Female	90	4.000	.0	.0	1	4	4
Female	100	4.666	.816	.666	6	4	6
Male	120	4.000	.0	.666	6	4	6
Female	120	4.500	1.000	.0	1	4	4
Female	130	5.000	.0	.0	1	5	5
Male	140	5.166	.408	.166	6	5	6
Female	140	4.000	.0	.0	2	4	4

Table 22. Results of Sort Procedure: TO vs AGE by R

Race	Age in Weeks	Mean	Standard Deviation	Variance	Observations	Minimum Value	Maximum Value
White	18g	2.800	1.780	3.171	15	0	5
Negro	18g	1.666	1.614	2.606	12	0	5
Latin	18g	3.333	.577	.333	3	3	4
Asian	18g	3.000	.0	.0	1	3	3
White	28g	3.724	2.078	4.320	69	0	11
Negro	28g	3.450	1.960	3.843	40	0	7
Latin	28g	3.928	1.730	2.994	14	0	6
Asian	28g	3.500	2.121	4.50	2	2	5
White	38g	6.129	2.452	6.015	62	0	13
Negro	38g	5.384	2.289	5.242	39	1	12
Latin	38g	5.410	2.009	4.037	39	0	10
Asian	38g	5.000	.707	.500	5	4	6
White	10	6.000	2.371	5.625	17	3	11
Negro	10	6.400	1.837	3.377	10	3	9
Latin	10	5.250	1.215	1.477	12	4	8
White	20	5.625	1.505	2.267	8	3	8
Negro	20	7.000	2.645	7.000	3	5	10
Latin	20	7.200	1.923	3.700	5	5	10
White	30	6.333	2.081	4.333	3	4	8
Negro	30	5.600	1.675	2.800	5	4	8
Latin	30	6.000	1.414	2.000	2	5	7
White	40	4.250	1.258	1.583	4	3	6
Negro	40	6.600	2.408	5.800	5	4	10
Latin	40	12.000	.0	.0	1	12	12
White	50	8.000	.0	.0	2	8	8
White	60	9.000	.0	.0	1	9	9
Negro	60	7.000	1.414	2.000	2	6	8
Latin	60	8.500	2.121	4.500	2	7	10
White	70	6.250	1.892	3.583	4	5	9
White	80	4.000	.0	.0	1	4	4
Negro	80	6.000	.0	.0	2	6	6
White	90	8.333	2.309	5.333	3	7	11
White	100	5.750	2.362	5.583	4	4	9
Negro	100	9.000	.0	.0	2	9	9
White	120	6.666	3.785	14.333	3	4	11
Negro	120	5.500	2.121	4.500	2	4	7
Negro	130	8.000	.0	.0	1	8	8
White	140	5.000	.707	.500	5	4	6
Negro	140	5.000	.0	.0	1	5	5
Latin	140	4.500	.707	.500	2	4	5

Table 23. Results of Sort Procedure: Z vs AGE by R

Race	Age in Weeks	Mean	Standard Deviation	Variance	Observations	Minimum Value	Maximum Value
White	18g	2.266	1.387	1.923	15	0	4
Negro	18g	1.500	1.314	1.727	12	0	4
Latin	18g	3.333	.577	.333	3	3	4
Asian	18g	3.000	.0	.0	1	3	3
White	28g	2.985	1.311	1.720	69	0	5
Negro	28g	2.625	1.314	1.727	40	0	4
Latin	28g	3.571	1.504	2.263	14	0	5
Asian	28g	3.000	1.414	2.000	2	2	4
White	38g	4.209	1.042	1.086	62	1	6
Negro	38g	3.871	.863	.746	39	0	5
Latin	38g	3.974	.959	.920	39	3	5
Asian	38g	3.800	.447	.200	5	1	4
White	10	3.941	1.088	1.183	17	1	6
Negro	10	4.600	.843	.711	10	3	6
Latin	10	4.166	.577	.333	12	3	5
White	20	4.125	.834	.696	8	3	5
Negro	20	4.333	.577	.333	3	4	5
Latin	20	5.000	.707	.500	5	4	6
White	30	4.666	.577	.333	3	4	5
Negro	30	4.200	.447	.200	5	4	5
Latin	30	5.000	1.414	2.00	2	4	6
White	40	3.500	.577	.333	4	3	4
Negro	40	5.200	1.095	1.200	5	4	6
Latin	40	6.000	.0	.0	1	6	6
White	50	5.000	.0	.0	2	5	5
White	60	6.000	.0	.0	1	6	6
Negro	60	5.000	1.414	2.000	2	4	6
Latin	60	5.000	.0	.0	2	5	5
White	70	5.000	.816	.666	4	4	6
White	80	4.000	.0	.0	1	4	4
Negro	80	5.000	1.414	2.000	2	4	6
White	90	5.000	1.000	1.000	3	4	6
White	100	4.250	.500	.250	4	4	5
Negro	100	5.500	.707	.500	2	5	6
White	120	4.666	1.154	1.333	3	4	6
Negro	120	4.000	.0	.0	2	4	4
Negro	130	5.000	.0	.0	1	5	5
White	140	7.200	1.482	2.200	5	5	9
Negro	140	6.000	.0	.0	1	6	6
Latin	140	6.500	.707	.500	2	6	7

Table 24. Analysis of LSMEANS of R Adjusted by Log AGE Means

RACE	LTO LSMEAN	STD ERR LSMEAN	PROB - (T) HO:LSMEAN=0	PROB- (T) I/J	HO:LSMEAN(I)=LSMEAN(J) 1	2	3	4
WHITE	0.73417415	0.01415275	0.0001	1	.	.1552	.2164	.7923
NEGRO	0.70154225	0.01801947	0.0001	2	.1552	.	.0234	.4807
LATIN	0.76702123	0.02244192	0.0001	3	.2164	.0234	.	.8535
ASIAN	0.75325551	0.07102557	0.0001	4	.7923	.4807	.8535	.

VITA

William Cesar Rodriguez, III was born in Altoona, Pennsylvania on August 4, 1954. He attended elementary schools in Memphis, Tennessee, and was graduated from Overton High in May 1973. The following September he entered The University of Tennessee, Knoxville. After two years of study he left the university to work in research at The University of Tennessee Medical School.

In September 1978 he returned to The University of Tennessee, Knoxville, and in March 1981 he received a Bachelor of Arts degree in Anthropology. In the spring of 1981 he started graduate school at The University of Tennessee, Knoxville, and began study toward a Master's degree. This degree was awarded in August 1982.

He is married to the former Karleen Katz of Nashville, Tennessee. On September 3, 1984 Karleen and William announced the birth of their first child Christina Victoria Moreau.