SKELETAL AGE CHANGES IN THE CHIMPANZEE[1]

ELLIS R. KERLEY,[2]

The Armed Forces Institute of Pathology and the Veterans Administration Central Laboratory for Anatomic Pathology and Research, AFIP, Washington, D. C. 20305

ABSTRACT

The skeletons of thirty chimpanzees of known ages from birth through thirty-five years were examined for gross, radiographic, and microscopic changes that could be associated with age. Anthropometric measurements were taken, and standardized radiograms of the stripped bones were measured for correlation with age, sex, and constitutional variations.

The age ranges during which certain epiphyses were found in the process of fusion are presented. These data extend the ability to determine age in the chimpanzee by epiphyseal closure through adolescence into adulthood. Additional changes in the costal cartilages and sternal ends of the ribs, the pubic symphysis, and the inferior angle of the scapula cover the age period of late adolescence and young adult life. Changes in the microscopic structure and resorptive patterns of bone provide additional information regarding age that supplements gross and radiographic appearance.

As part of a long range investigation into the effects of age, sex, and constitutional variations on skeletal structure in the chimpanzee, age changes in the gross, radiographic, and microscopic structure of bone have been examined in thirty chimpanzees of known age from birth through thirty-five years. Routine anthropometric measurements were obtained on sixteen of these chimpanzees just prior to exsanguination at the Yerkes Laboratory of Primate Biology in Orange Park, Florida. These were standard measurements according to Martin (1928), Hooton (1946), and Hrdlicka (Stewart, 1952), except that they were made with the chimpanzees anesthetized and supine. A few special measurements were added to demonstrate specific relationships among anatomic areas and body regions.

After they were fixed in formalin, the stripped skeletons were sent to the Armed Forces Institute of Pathology, where the individual bones were X-rayed by standardized procedure.[3] These radiograms were ex-

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[1] The condensed form of a paper presented November 5, 1964 as part of a symposium on primates at the Tulane University Delta Regional Primate Research Center in Covington, Louisiana.

[2] Present address: Department of Anthropology, University of Kansas, Lawrence, Kansas 66045.

[3] The stripped bones of each chimpanzee were placed on a cardboard cassette at a fixed distance of 42 inches from tube to cassette and radiographed in both anterior-posterior and lateral planes. Since anatomic structure was of primary interest rather than radio-density, exposure time varied with the size of the bones, but the basic 55 kilovolt and 50 milliampere settings of the machine remained constant. All radiographic metric comparisons were of measurements of radiographs made in this same standardized manner, but certain radiographic measurements were checked against comparable gross bone measurements to determine the amount of enlargement resulting from x-ray dispersion. Since the stripped bones were in contact with the cassette at their lowest point and less than four inches away from it at their maximum distance, enlargement was generally less than 5% even at the edges of the film.

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amined, and the state of epiphyseal closure was recorded. The long bones were measured from the radiograms to establish growth rates and differences in relative size. Diameters, widths, and cortical thicknesses were measured in addition to bone lengths. Since long bones derive most of their length from the metaphyseal growth plates, the intermetaphyseal lengths were measured, as were the functional lengths between the articular surfaces of each long bone. Indices were devised that would show the ratios of long bone length to height, width and cortical thickness to length, and bone size to body weight. Skeletal structure was related to the anthropometry and ponderal index as well (Table 1).

After they were X-rayed, the bones were cut on a bandsaw into blocks appropriate for standardized microscopic sections. The ends of the major long bones were cut in a longitudinal plane to provide information about the metaphyseal growth plate, the articular cartilage and subchondral plate, and the cancellous bone. Ground cross-sections were made of the middle portion of the diaphyses of the major long bones to examine variations in the microscopic structure. In man, the cancellous bone undergoes changes related to age in the metaphyseal and epiphyseal ends of some long bones (Schranz, 1959) (Hansen, 1953-54), and there are microscopic changes in the structure of the mid-shaft area that have been well-correlated with age (Amprino and Bairati, 1936) (Jowsey, 1960) (Kerley, 1965).

Sections of the clavicle, ribs, vertebrae, pelvis, hand, and foot also were made. These were chosen to examine differences in bone growth and metabolism, and because they represent areas that have known variations in man. Vertebrae show differences in density with age in man (Broman, Trotter and Peterson, 1958) (Trotter, Broman and Peterson, 1959), and with sex (Trotter, Broman and Peterson, 1959) (Seale, 1959). The pelvis exhibits a high degree of sexual dimorphism in man (Boucher, 1957) (Hoyme, 1957) (Washburn, 1948); the pubic symphysis (Todd 1920-21) (Brooks, 1955) (McKern and Stewart, 1957) and sternal end of the clavicle (Todd and D'Errico, 1928) have variations that are correlated with age, as do the sternal ends of the ribs (McKern and Stewart, 1957). These gross and microscopic skeletal variations that have been correlated with age and sex in man serve as guide-posts for examining age changes in the chimpanzee, one of man's closest relatives, which should exhibit age variations similar to those found in man.

Results

Although the bulk of this research was designed as a long-term project that is in process, certain results are of immediate interest to researchers in primatology and can be presented for the first thirty chimpanzees of documented age in the larger series. These results will present the age ranges during which certain skeletal changes occurred in this series of thirty chimpanzees whose ages were recorded from birth.

Figures 1-4 show the rates of growth in length for the major long bones of the arm and leg from birth until well past the age

Table I.
Anthropometric and Radiographic Indices

Sitting height/stature	Forearm/upper arm girth
Stature/arm span	Lower/upper leg girth
Thoracic index	Leg length/arm length
Hip width/chest width	Thigh/lower leg length
Abdominal/chest girth	Foot width/leg length
Biacromial/sitting height	Hand width/arm length
Femur length/stature	Humerus length/stature
Femoral shaft width/length	Humeral shaft width/length
Femoral cortex/length	Humeral cortex/length
Femoral shaft width/stature	Humeral shaft width/stature
Tibia length/stature	Radius length/stature
Tibial shaft width/length	Radial shaft width/length
Tibial cortex thickness/length	Radial cortex thickness/length
Tibial shaft width/stature	Radial shaft width/stature
Clavicle/humerus length	Bi-iliac/stature
Clavicle width/length	Bi-iliac/bi-acromial

when growth in length has been completed. These measurements were made from radiographs of bones that had been disarticulated, stripped of most of the soft tissue, and include the bony parts of the epiphyses. They represent the maximum length of the bone on the radiographs and include the width of the metaphyseal growth plates. The rates

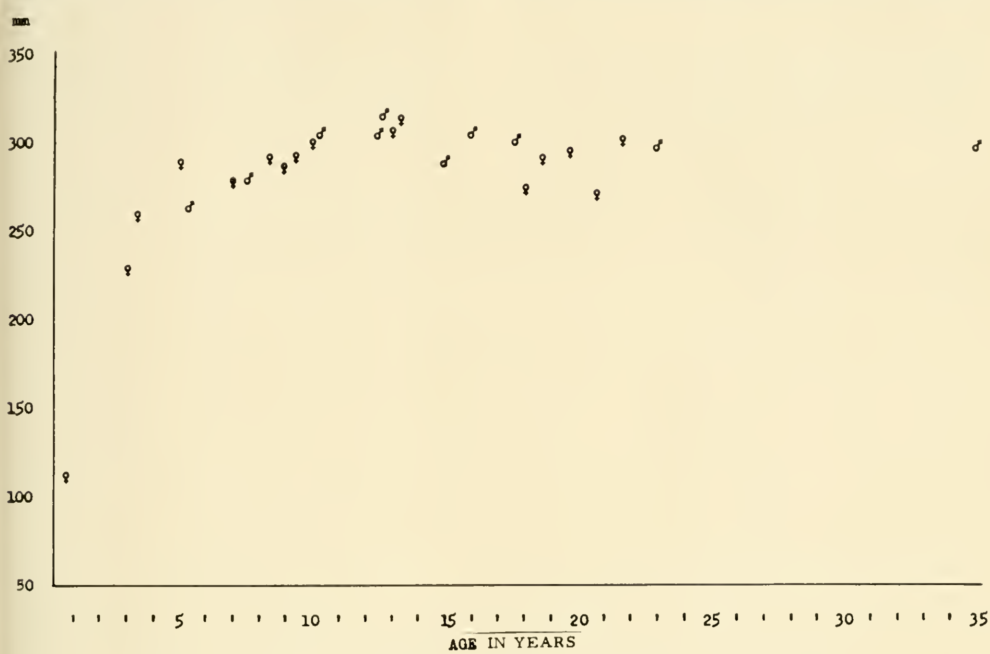

Figure 1. Rate of growth in overall length of the humerus.

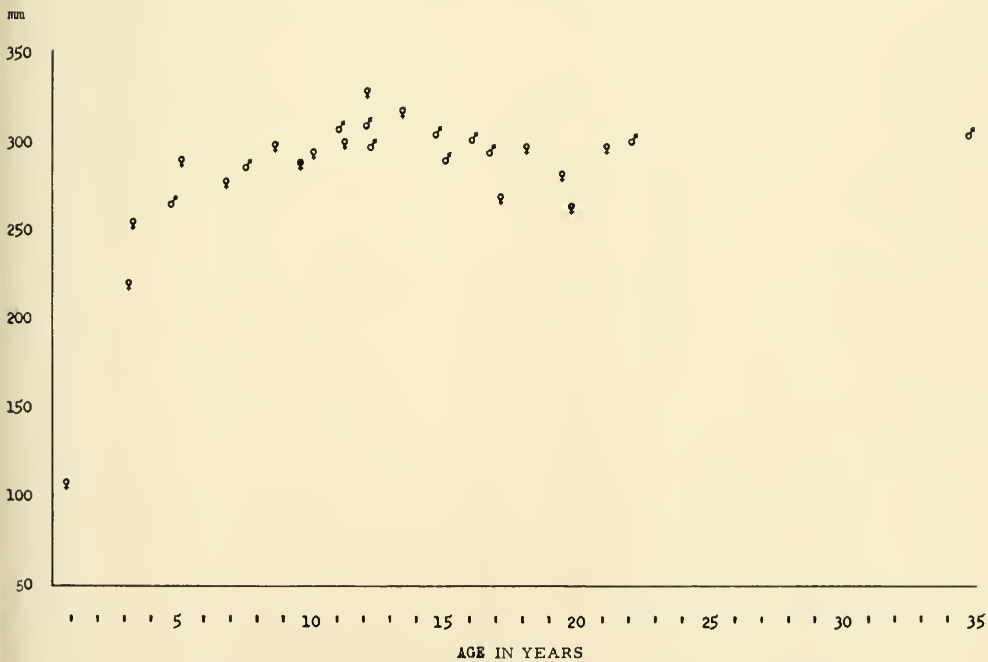

Figure 2. Rate of growth in overall length of the femur.

of growth in length level off at about ten years of age and there is little additional growth in length after age twelve. These results are in general agreement with those previously reported by Gavan (1953) from a study of anthropometric measurements of living chimpanzees. Some of the same chimpanzees measured by Gavan were included

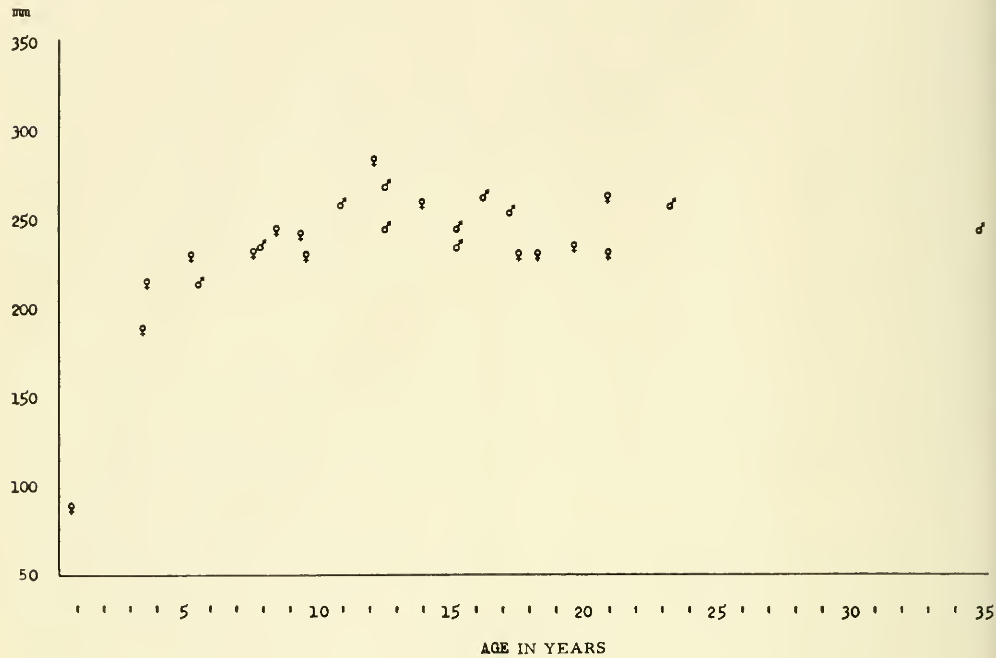

Figure 3. Rate of growth in overall length of the tibia.

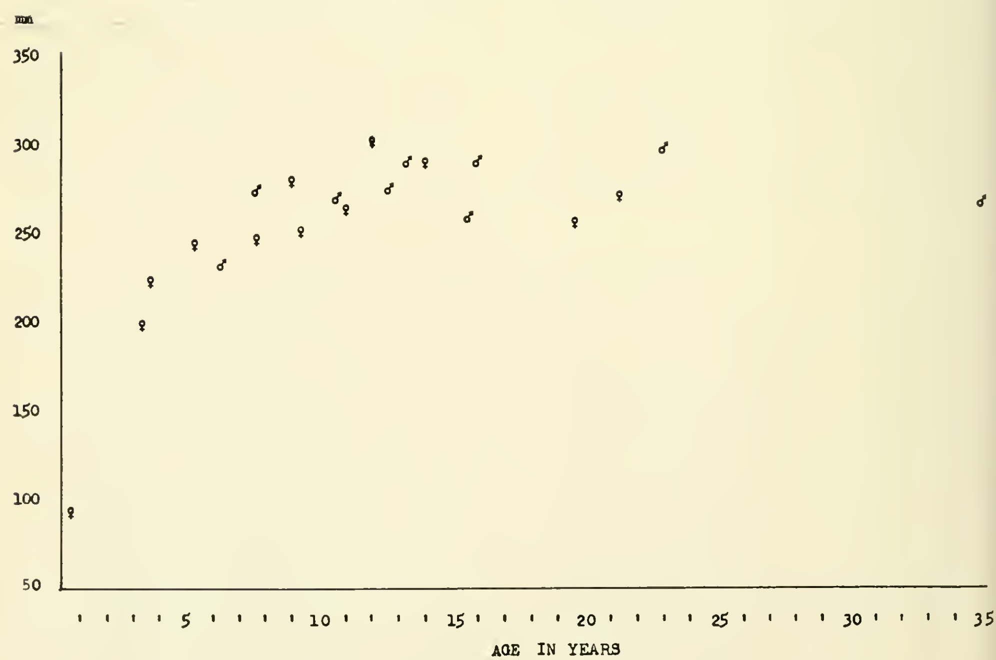

Figure 4. Rate of growth in overall length of the radius.

in the present study. However, they were measured at the time of death in this study at later ages than when Gavan measured them. In this report, growth rate curves were derived from a cross-sectional study of thirty chimpanzees rather than a longitudinal study of the continuing growth at periodic intervals in individual animals, as in Gavan's study. In both types of growth study the rates of growth are determined by plotting size against age. In the present study, the overall lengths of the major long bones were derived from radiographic measurements.

The ages at which various epiphyses fuse to the diaphyses of long bones and the segments of certain other bones fuse together were recorded within the limits of the sam-

TABLE II. AGES OF EPIPHYSEAL UNION

AGE IN YEARS	0 ' '	' ' 5	' ' ' ' 10	' ' ' ' 15	' ' ' ' 20	' ' ' ' 25 ' ' ' ' 30 ' ' ' '	35
SEX	♂ ♂	♀ ♀	♀♂ ♀ ♂ ♀♀ ♀	♀ ♀♂? ♀♂ ♂	♂ ♂♂♂? ♀ ♀ ♀♀	♂	♂
EPIPHYSES & SEGMENTS							
PROXIMAL HUMERUS	- -	- -	-- - - -C X	C CCC CX	X C XXX X X XX	X	X
DISTAL HUMERUS	- -	- -	CC C X XX X	X XXX XX	X X XXX X X XX	X	X
MEDIAL EPICONDYLE	- -	- -	-- C C XX X	X XXX XX	X X XXX X X XX	X	X
PROXIMAL RADIUS	- -	- -	-- - - -C X	X XXX XX	X X XXX X X XX	X	X
DISTAL RADIUS	- -	- -	-- - - -- -	C CCX CX	X X XXX X X XX	X	X
PROXIMAL ULNA	- -	- -	-- C -X X	X XXX XX	X X XXX X X XX	X	X
DISTAL ULNA	- -	- -	-- - - --	C CCX CX	X X XXX X X XX	X	X
METACARPALS	- -	- -	-- - - -X	X XXX XX	X X XXX X X XX	X	X
PHALANGES	- -	- -	-- - - CX	X XXX XX	X X XXX X X XX	X	X
SCAPULAR BORDER	- -	- -	-- - - -- C	- CC -C	C C XXX X X X	X	X
ACROMIAL PROCESS	- -	- -	-- - - -- X	XX X	X X XX X X		X
CORACOID PROCESS	- -	- -	- - -X X	XX X	X X XX X X		X
STERNAL CLAVICLE END	- -	- -	-- - -- -	- -- --	- - CCX C X X	X	X
STERNUM	- -	- -	- - - -- -	-C CC	C C CCC C C		X
RIBS	- -	- -	-- - -- X	XX X	X X XXX X X XX	X	X
CERVICAL VERTEBRAE	- -	- -	-- - - --	C XXX X	X X XXX X X X	X	X
THORACIC VERTEBRAE	- -	- -	-- - - -C -	C CCX CC	X X XXX X X XX	X	X
LUMBAR VERTEBRAE	- -	- -	-- - - -C -	C CCX CC	X X XXX X X XX	X	X
SACRUM	-	- -	-- - - -- -	- CCC CC C	C C CCC C C CC	C	X
ILIAC CREST	- -	- -	-- - - -C C	C - C -C C	C X XXX X X XX	X	X
TRI-RADIAL PLATE	- -	- -	-- C - XX X	X XXX XX X	X X XXX X X XX	X	X
ISCHIUM	- -	- -	-- - - -C -	C -CX CX C	C X XXX X X XX	X	X
FEMORAL HEAD	- -	- -	-- - - CX X	X XXX XX X	X X XXX X X XX	X	X
GREATER TROCHANTER	- -	- -	-- - - CC X	X XXX XX X	X X́ XXX X X XX	X	X
LESSER TROCHANTER	- -	- -	C - C X	X XXX XX X	X X XXX X X XX	X	X
DISTAL FEMUR	- -	- -	-- - - -C X	C XX CX X	X X XXX X X XX	X	X
PROXIMAL TIBIA	- -	- -	-- - - -C X	C XX CX X	X X XXX X X XX	X	X
DISTAL TIBIA	- -	- -	-- - - -C X	X XXX XX X	X X XXX X X XX	X	X
PROXIMAL FIBULA	- -	- -	-- - - -C X	X XX XX X	X X XXX X X XX	X	X
DISTAL FIBULA	- -	- -	-- - - -X X	X XXX XX X	X X XXX X X XX	X	X
CALCANEUS	- -	- -	-- - - X X	X XXX XX X	X X XXX X X XX	X	X
METATARSALS	- -	- -	-- - - -X X	X XXX XX X	X X XXX X X XX	X	X
PHALANGES	- -	- -	-- - - CX X	X XXX XX X	X X XXX X X XX	X	X
AGE IN YEARS	0 ' '	' ' 5	' ' ' ' 10	' ' ' ' 15	' ' ' ' 20	' ' ' ' 25 ' ' ' ' 30 ' ' ' '	35

Explanation of symbols: - = epiphysis open C = epiphysis in the process of closing X = epiphysis completely closed ple from the examination of Roentgenograms of the stripped bones. Radiographic obseravtions were confirmed by histologic sections of the epiphyseal-metaphyseal areas in the long bones. The results are presented in Table II. The sequence of epiphyseal closure in this sample is similar to that reported by Schultz (1940). The distal end of the humerus begins to fuse around five years of age and is the first epiphysis to complete fusion. The proximal end of the ulna and the triradiate cartilage separating the three elements of the innominate begin fusing shortly afterwards. Some epiphyses, such as those in the hand, ankle, and foot, complete the process of fusion shortly after they begin it, while others, those of the proximal humerus and the iliac crest, may take several years to complete fusion. There appears to be relatively little variability in the age range during which fusion occurs in some areas, as in the elbow, while fusion in the epiphyses of the knee and proximal humerus occurs over a much longer time span.

The approximate ages of chimpanzees of unknown age can be determined by the data that have been published on age changes in dental eruption (Nissen and Riesen, 1964) and by the appearance of secondary ossification centers (Nissen and Riesen, 1949a, 1949b) (Schultz, 1956). The data that have been published permit the determination of age in the chimpanzee up to about eleven or twelve years—the same range covered by Gavan's growth study. The data presented in Table II extend the ability to determine age up through adolescence and well into adulthood.

Direct observation of radiographs of monkeys of various skeletal ages has shown that the costal cartilages of most monkeys, both New World and Old World, begin to calcify while deciduous dentition is still present.[1] The calcium is deposited in the center of the costal cartilages in the form of flat bars that almost connect the ribs and sternum. The process begins early in childhood in some monkeys. In man, the costal cartilages calcify in middle and old age, and in some aged humans the calcified cartilage has been resorbed and replaced by bone. When radiographs of the chimpanzee costal cartilages were examined, those of the older chimpanzees showed typical patterns of calcification (Figure 5). These patches of calcified cartilage became radiographically discernible as early as seventeen years of age, which is about fourteen years later than they appear in monkeys, and much earlier than calcification can be seen in the costal cartilages of man. The age distribution of discernible costal calcification in the chimpanzee is presented in Table III.

[1] The skeletons of about 100 other primates of undocumented age including both Old World and New World monkeys were made available for study by the Delta Regional Primate Research Center of Tulane University. These have been x-rayed and histologic slides have been prepared for selected representative specimens. Not all of the radiographs or histologic slides of these other primates have been measured or analyzed yet, but it is apparent that several of the age changes described in the chimpanzee in this paper occur earlier in other primates while much of the deciduous dentition is still present and before many of the epiphyses have begun to fuse.

TABLE III.

RADIOGRAPHIC AGE CHANGES IN THE CHIMPANZEE

AGE IN YEARS	0 ' ' ' ' 5 ' ' ' ' 10 ' ' ' ' 15 ' ' ' ' 20 ' ' ' ' 25 ' ' ' ' 30 ' ' ' ' 35
PUBIC SYMPHYSIS IN THE PROCESS OF FUSION	- - -- --- - --- ------- - --XXX X - X X
CALCIFICATION IN THE COSTAL CARTILAGE	- - -- --- - --- --- - -XXXX X XX
OSSIFICATION OF THE STERNAL RIB ENDS	- - -- --- - --- --- - --XXX - XX
SEX	♀ ♂ ♀♀ ♀♂♀ ♂ ♀♀♀ ♀♀♂♀♂♀♂ ♂ ♂♂♂♀♀ ♀ ♀♀ ♂ ♂

\- No radiographic evidence of fusion, calcification, or ossification.
X Radiographic evidence of progressive fusion, calcification, or ossification.

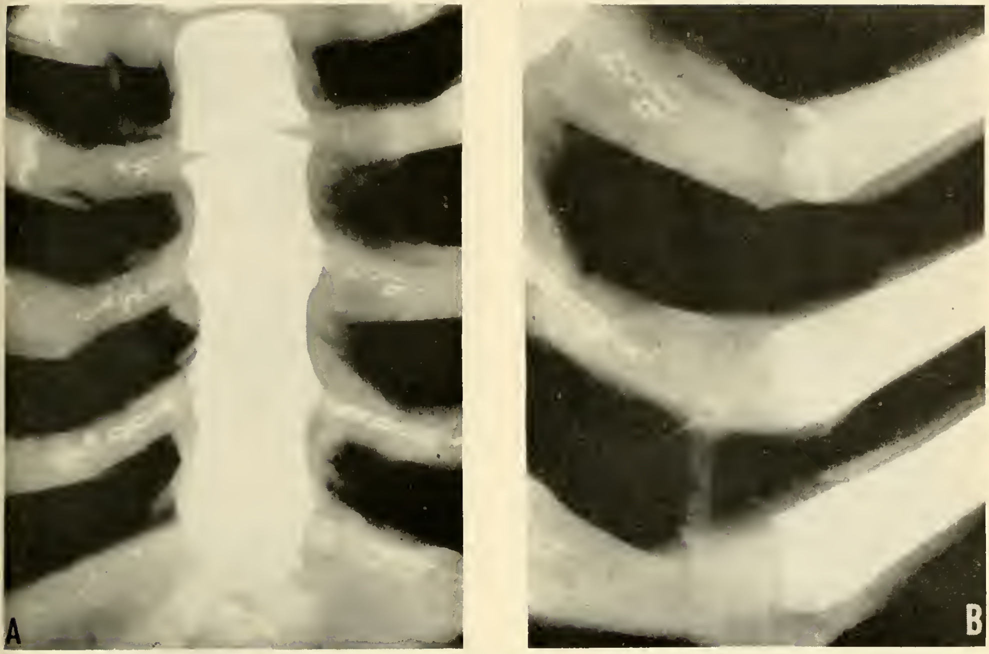

Figure 5. Age changes in the sterno-costal area. **A.** Calcification in the costal cartilage of an 18 year old female chimpanzee. **B.** Progressive ossification of the rib ends of a 21 year old female chimpanzee.

An additional change occurs in adult chimpanzees in the area of the sternal ends of the ribs that is also correlated with age. There is a continuation of ossification from the periosteal surface of the rib at the costo-chondral junction that produces a progressive deepening, or cupping, of the end of the rib. This is accompanied by ossification from the center of the costo-chondral junction which projects into the costal cartilage (Figure 5). The age distribution for radiographically discernible costo-chondral ossification follows the same basic pattern as the calcification of the costal cartilages with regard to age (Table III).

The two halves of the pubic symphysis begin to fuse at about eighteen years of age in the chimpanzee (Figure 6), and there is bony ankylosis across the upper third of the symphysis by age thirty-five. The ages at which this fusion can be seen both radiographically and microscopically are shown in Table III. In man, the two halves of the pubic symphysis do not normally fuse at any age, but in other animals, including many of the primates, the symphysis fuses over as much as half its length at a fairly early age. Symphyseal union in the chimpanzee has been noted before (Schultz, 1956), but the age at which fusion occurs has not been documented.

There are age changes in the microscopic structure of the mid-shaft area of chimpanzee long bones that are quite similar to those found in man (Kerley, 1965). Osteones increase in number and complexity of arrangement with the increasing age of the chimpanzee as they replace circumferential lamellar bone in the cortex. Osteoclasts burrow channels along the length of the bone through the circumferential bone beginning shortly after birth. These channels are gradually filled in turn with concentric layers of lamellar bone and become osteones. As the osteones become numerous, fragments of old osteones are left surrounding newer ones where osteoclastic resorption had removed portions of them. In old age, there is very little circumferential lamellar bone, and most of the cortex is composed of densely-packed osteones and fragments of old osteones.

The areas of the cortex that undergo intensive resorptive activity at any given time also vary with age. The resorptive channels that run longitudinally along the shafts of

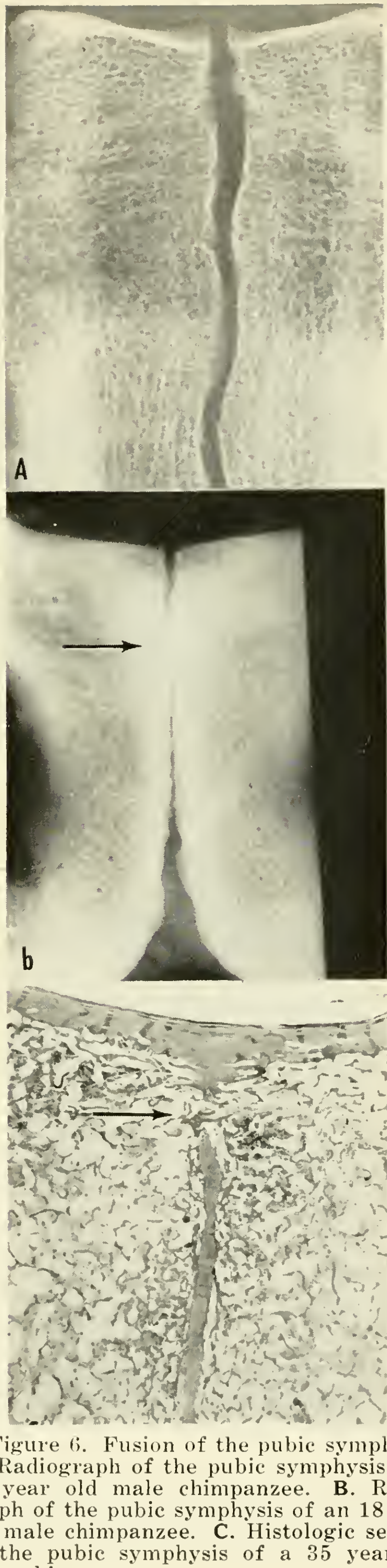

Figure 6. Fusion of the pubic symphysis. **A.** Radiograph of the pubic symphysis of a 14 year old male chimpanzee. **B.** Radiograph of the pubic symphysis of an 18 year old male chimpanzee. **C.** Histologic section of the pubic symphysis of a 35 year old male chimpanzee.

long bones and fill in with concentric lamellae to form osteones later are diffusely spaced throughout the thickness of the cortex in infancy and early childhood (Figure 4).

During late childhood and early adolescence in man, between 10 and 17 years of age, there is a concentration of resorptive channels in the peripheral part of the cortex near the periosteal surface, as a result of increased osteoclastic activity prior to the replacement of the remaining sheets of subperiosteal lamellar bone by osteones in late adolescence. This peripheral concentration of resorptive cavities can be seen in chimpanzee long bones between five and ten years of age. In the normal chimpanzee slides examined, from around eleven years until age thirty-five there is little cortical resorption and the cortex is rather homogeneously osteon bone that is more densely packed with osteones and fragments of old osteones as age increases.

Histologic age changes in resorptive patterns have been described in the long bones of the leg in man (Kerley, 1962), a close relative of the chimpanzee. The patterns of resorption are quite similar in both, except that the inner third of the cortex undergoes extensive resorption in man beginning about age sixty-five in males and earlier in females, whereas the oldest chimpanzee (age 35) in this series showed no evidence of medullary resorption. However, it is reasonable to predict that the same pattern of meduallary resorption might be present in more aged male or aging female chimpanzees. Comparable stages in the patterns of resorption are shown in Figure 7 for chimpanzee (E-H) and human (A-D) femurs.

There is relatively little change in proportion that can be related to age in the chimpanzee after about three years of age. The most notable exceptions are in the width of the hip and shoulder areas, the ratio of forearm to upper arm, and the relative thickness of the cortex in long bones. The clavicle continues to grow slightly after the humerus has completed its growth in length. The length of the clavicle was about 38% of the length of the humerus at three years of age and increased to 45% by age 22 in this series. In the hip region, the biiliac width increased from 76% of the length of the femur at one-and-a-half years of age to 96% by age twenty-two. The length of the forearm decreased from 106% of the length of the upper arm at one year of age to 95% by age twenty-three. The

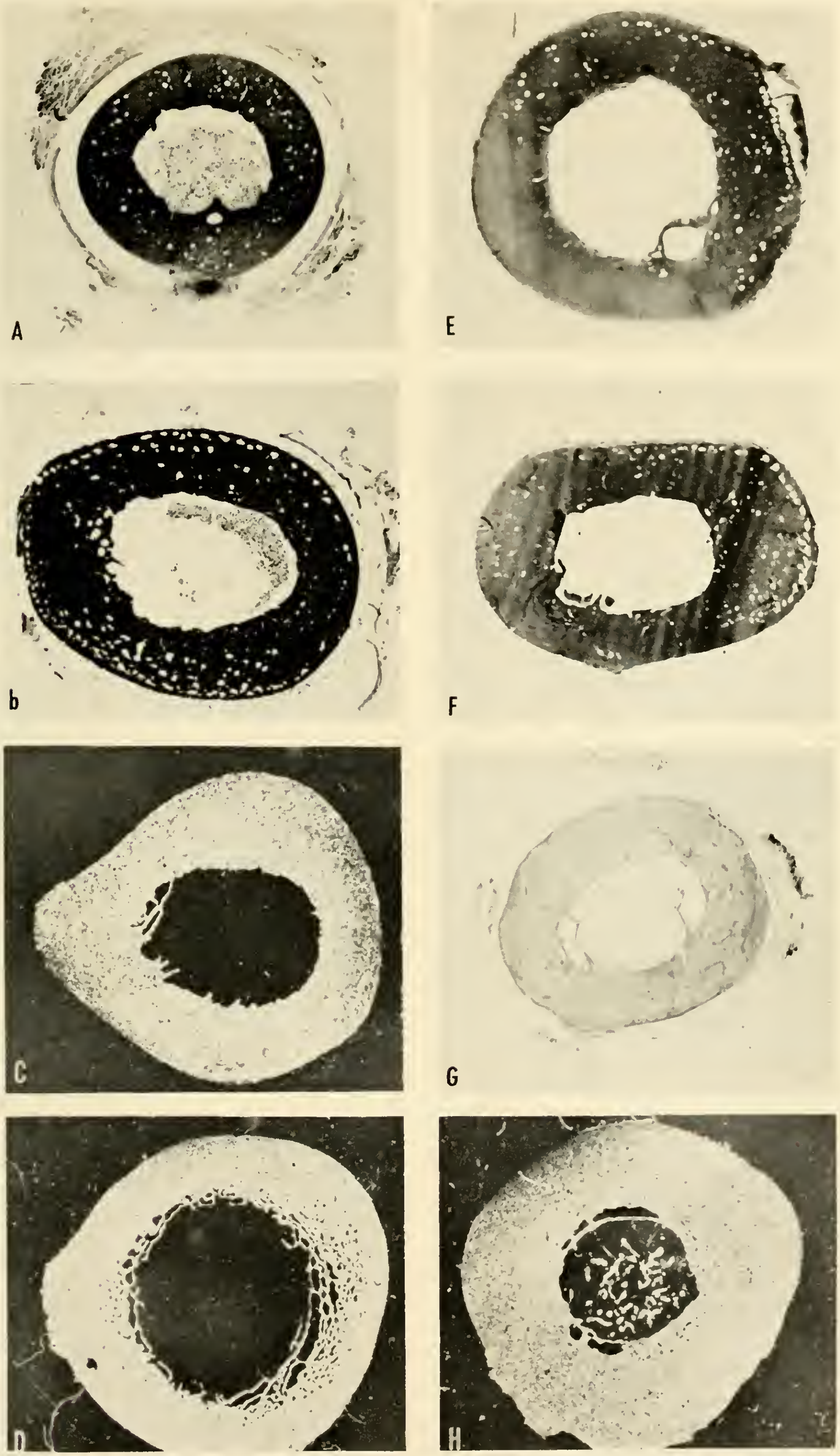

Figure 7. Patterns of cortical resorption. **A.** Cross-section of a four year old human femur. **B.** Cross-section of a 12 year old boy's femur. **C.** Ground cross-section of the femur of a 38 year old man photographed with polarized light. **D.** Ground cross-section of the femur of a 75 year old man photographed with polarized light. **E.** Cross-section of the femur of a three year old female chimpanzee. **F.** Cross-section of the tibia of a seven year old female chimpanzee. **G.** Cross-section of the femur of a 14 year old female chimpanzee. **H.** Ground cross-section of the femur of a 35 year old male chimpanzee photographed with polarized light.

lateral diameter of the midshaft of the major long bones of the arm and leg increased with age to adulthood. The relative lateral diameter of the mid-shaft of the femur, where the change was the most pronounced, increased from 7% of the total length of the femur at 3½ years of age to 10% by fourteen. From birth to three years of age the mid-shaft diameter decreased from 12% of the length at birth to 7% at three years, as the bones lengthened rapidly, and developed thin shafts.

There were rather minor differences in skeletal structure or proportions between male and female chimpanzees. As might be expected, the most notable differences occurred in the areas of the pelvis that are involved in parturition. The bi-ischial width as measured from radiographs is wider in proportion to the bi-iliac width in females, reflecting a relatively larger pelvic outlet than male chimpanzees have. In addition, the bi-iliac width is greater in proportion to the length of the femur in females than in males, making the pelvis wide relative to the thigh length in females. The hip width is greater in females when related to the sitting height, whereas males have a larger average chest circumference relative to the sitting height.

Of all the indices computed, the only significant variation that did not vary with age or sex but appeared related to body type was the thickness of the femoral cortex relative to the total length of the femur. The relative cortical thickness of the femur was greater in endomorphic and mesomorphic chimps than in those that were ectomorphic. The ponderal index (height divided by the cubic root of the weight) is a measure of the compactness or linearity of an individual. Compact chimps with an index under 40 had relatively thick femoral cortices, whereas the linear ones with an index over 40 had relatively thin femoral cortices. Thus the weight bearing and muscle action seemingly directly affect the relative thickness of the femoral cortex. Additional factors not apparent from this study seem to affect the cortical thickness of the humerus.

The epiphysis of the inferior angle of the scapula ossifies and fuses to the scapula in a distinctive manner in the chimpanzee, and the formation and fusion of this epiphysis provide the basis for an additional parameter in estimating chimpanzee age in the range from six to eighteen years. This epiphysis is a large one in the chimpanzee, and it ossifies over a period of several years, beginning as one or several small centers in the outer

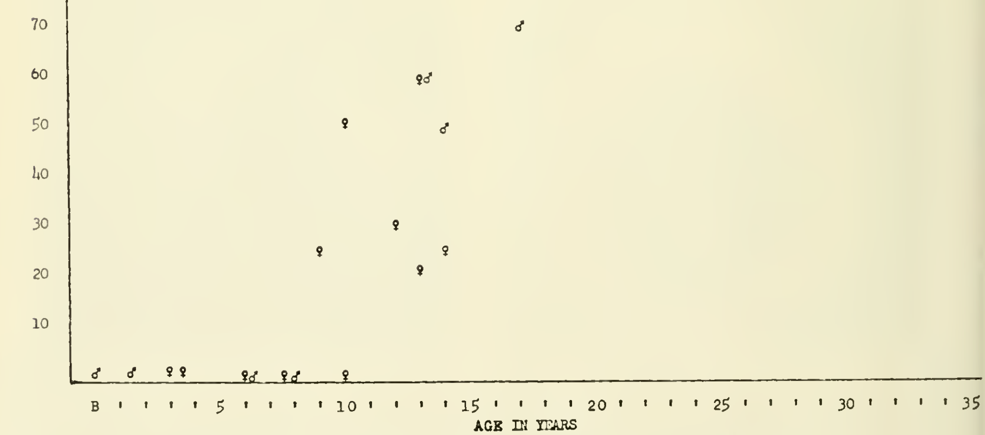

Figure 8. Epiphysis of the inferior scapular angle.

rim of the cartilage that forms the inferior angle. The outer part of the epiphysis ossifies first, forming a border of bone around a large area of cartilage at the inferior angle. As the epiphysis matures, the center part ossifies and the whole epiphysis fuses to the scapula. Owing to the size and manner of ossification, the percentage of the total epiphysis that is ossified at a given time can be estimated from radiographs or from the ossified portion of the epiphysis itself. There is a positive relationship between age and the percentage of the epiphysis that is ossified in the chimpanzee (Figure 8). In recording the data used in Figure 8, complete bony formation and the fusion of the epiphysis to the scapula with obliteration of the growth plate separating them was considered 100% ossification.

Discussion

The manner in which age changes occur and the times of epiphyseal union indicate that chimpanzees have a closer phylogenetic relationship to man than to either New World or Old World monkeys. Certain age changes in the pubic symphysis, sternum, and costal cartilages are found in monkeys from childhood on, whereas in chimpanzees they are modified and begin around seventeen years of age. In monkeys and other mammals these changes are much more extensive than they are in the chimpanzee and begin rather early in life, while in man they occur in middle age, and no fusion occurs at the pubic symphysis. The microstructure of the diaphyses of long bones of chimpanzee resembles that of man more than it does that of monkeys by microscopic comparison of histologic cross sections. As might be expected, all of these factors indicate that the chimpanzee falls between man and the monkeys phylogenetically, with a stronger resemblance to man than to monkeys.

These age changes in the costo-chondral areas, epiphyseal union, the age changes in microscopic structure of long bone diaphyses and the regression of cancellous bone in metaphyses all suggest that the chronologic age in years for a given skeletal age in the chimpanzee is between two and three times that of most monkeys and about two-thirds that of humans of the same skeletal age. After growth in length of the long bones of the extremities has been completed, a small amount of growth continues in the width of the shafts of the long bones, at the ends of ribs, at the sternal end of the clavicle, and in the lateral dimensions of the pelvis.

There is relatively little sexual dimorphism in chimpanzees other than differences in size between male and female. The skeletal variations that do exist between the sexes are greater relative width in the pelvic area of females and relatively larger chests in the males. These differences perhaps have some selective advantage in mate acquisition for males and in parturition for females. Chimpanzees exhibit remarkably little sex differentiation in the skeleton when compared to other large anthropoids.

Summary and Conclusions

The bones of thirty chimpanzees ranging in age from birth to thirty-five years were examined, X-rayed, and made into histologic sections. The radiographs and histologic sections were then compared with the gross skeleton, and information obtained from all three sources was correlated with age and sex. The ages at which various epiphyses began fusing with the metaphyses and the ages which fusion had been completed in all chimpanzees were recorded. Additional age changes were found in the costal cartilages, pubic symphysis, and the sternal ends of the ribs. These all began about eighteen years of age, when the epiphyses of most of the long bones had just completed fusion.

Microscopically, there were age changes in the structure of the long bones that are comparable to those found in man. Osteones and fragments of old osteones increased in number with advancing age, while lamellar bone and non-Haversian canals decreased. In addition, there were variations in the resorptive patterns of the mid-shaft areas of long bones that were associated with age and were very similar to those found in the long bones of man.

1. The state of epiphyseal union can be determined by gross examination, X-ray, or histologic slides, but the most reliable data are derived from all three when the epiphyses are in the process of fusing.

2. Specific age changes in the scapula, pubic symphysis, and costo-chondral areas add further information useful in determining age in the difficult period after the epiphyses have all fused.

3. Changes in the microscopic structure

and patterns of resorption are the normal result of advancing age in chimpanzees as well as in man. These changes must be taken into account in assessing any experimental results from an examination of the skeleton —particularly those that propose to evaluate nutritional results.

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