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The Ossa Supraternalia In Whites And American Negroes And The Form Of The Superior Border Of The Manubrium Sterni

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THE OSSA SUPRASTERNALIA IN WHITES AND AMERICAN NEGROES AND THE FORM OF THE SUPERIOR BORDER OF THE MANUBRIUM STERNI

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I. INTRODUCTION

In this presentation are described the results of an investigation of the variation and incidence of suprasternal bones and the form of the superior manubrial border on human and anthropoid sterna in the collections of the Hamann Museum of Western Reserve University. For access to the material and laboratory facilities the author is deeply indebted to Prof. T. Wingate Todd.

A total of 2218 human sterna in three series were examined. The first series comprised 1010 specimens, 544 white and 466 Negro. These bones were studied from roentgenograms checked when necessary by examination of the actual specimens. The roentgenograms had been taken by Prof. Todd over a number of years as the sterna became available from the dissecting room. By special provision the sterna had been removed from the cadavera with the clavicular ligaments attached and as far as possible intact. In this way minute episternal ossicles were detected which otherwise would have been lost in maceration. The second series included 1113 sterna, 776 white and 337 Negro, examined after maceration. The third series consisted of the roentgenograms of 65 juvenile sterna, 25 white and 40 Negro. The anthropoid series was composed of the macerated manubria of 61 gorillas, 38 chimpanzees and 8 orangs.

II. REVIEW OF THE LITERATURE

In most anatomical texts mention of suprasternal bones is limited to a brief description of the occasional ossicles with a suggestive statement concerning their morphological significance (11, 15, 23, 31, 41, 49, 54, 63, 71, 73, 82, 83, 87). The older works of Henle (36), Bardeleben (7), Gegenbaur (30), Poirier and Charpy (69), and Quain (14), give more extensive discussions which may no longer be considered adequate. Martin (58) summarizes studies of the incidence and variations of the suprasternalia.

Episternal bones were first mentioned in a short paragraph by Béclard in 1820(8):

Il existe quelquefois, et j'en possède des exemples sur des sternum d'environ trente-cinq ans, deux points osseux pisiformes, placés l'un de chaque côté, sur l'échancrure trachélienne du sternum. Ces points, que l'on peut appeler présternaux ou sus-sternaux, sont peut-être le rudiment de la fourchette ou clavicule furculaire de certains animaux.

The first detailed description, however, was furnished by Breschet in 1838(12), who stated that he had earlier directed the attention of Béclard to the ossicles, so that subsequent writers have generally acknowledged Breschet as the discoverer of episternal bones. Breschet's description, remarkable for its accuracy and completeness, was illustrated by several excellent figures. He described, precisely, episternal cartilages, separate episternal ossicles and episternal bones which had fused to the manubrium, and he emphasized the uniform position of the episternal structures on the posterior portion of the superior manubrial margin. His account is quoted in part:

Pendant l'exercice de nos fonctions de chef des travaux anatomiques de la Faculté de Médecine de Paris, nous avons eu assez souvent l'occasion de rencontrer des sternum dont l'extrémité supérieure était surmontée de deux noyaux osseux ou cartilagineux. Nous en avons remis plusieurs exemples à Béclard, qui s'occupait alors d'un travail sur l'ostéose, et il en a dit quelques mots dans un supplément de son mémoire....Nous avons de nouveau observé plusieurs cas d'existence de ces pièces osseuses à la partie supérieure du sternum, et ne voyant pas dans les traités d'ostéologie d'indications suffisantes de ces noyaux osseux, nous avons pensé qu'il ne serait pas sans intérêt de les décrire et de les faire représenter....[Describes cases.] L'extrémité claviculaire de cet os [sternum] offre tout-à-fait en dehors l'insertion du cartilage de la première côte au sternum, plus en dedans deux facettes articulaires, encroûtées de cartilages, pour recevoir la clavicule, et vers la partie la plus interne de ces surfaces, deux productions cartilagineuses dirigées en haut et inclinées un peu en arrière, séparées l'une de l'autre par l'intervalle qu'on nomme la fourchette. Ces corps rudimentaires non-seulement sont plus en dedans, mais encore ils sont inclinés plus en arrière que les surfaces qui reçoivent la clavicule. Ces productions se trouvent donc tout-à-fait en arrière et en dedans de l'insertion sternale du muscle sterno-mastoidien. Sur cet os desséché, ces corps n'étant que cartilagineux, sont faiblement exprimés; mais dans l'état frais ils étaient très distincts.

Ici l'on voie sur l'extrémité cervicale ou supérieure de cet os [sternum], tout-à-fait en dehors, deux larges surfaces articulaires, concaves de dedans en dehors, lisses, destinées à recevoir la clavicule. Ces surfaces sont séparées par une crête dirigée de devant en arrière, de deux autres facettes, beaucoup moins grandes, circulaires, regardant en haut, un peu arrière et en dehors, lesquelles surfaces sont surmontées de deux noyaux osseux, arrondis sur tous les points de leur étendue, excepté sur le côté par lequel ils sont en rapport avec le sternum. Quoique placés sur l'extrémité supérieure ou claviculaire du sternum, cependant une ligne transversale qui séparerait cet os en deux moitiés égales l'une antérieure et l'autre postérieure, laisserait en arrière les deux noyaux osseux, comparables, bien que plus volumineux, aux os pisiformes du carpe. Ces deux os sont unis entre eux, vers leur côté interne, par un ligament transversal. Une membrane synoviale recouvre toute la surface par laquelle ils sont en contact avec le sternum, et ils glissent sur ce dernier os auxquels ils sont unis par de petites fibres ligamenteuses circulaires. C'est donc une véritable diarthrose temporaire....Sur ces deux os [sterna], les petites pièces osseuses dont nous

faisons l'histoire, bien qu'unies solidement au sternum, permettent de voir bien nettement la ligne de séparation du sternum avec les os sus-sternaux. Sur toutes les pièces que nous avons observées, comme sur toutes celles que nous avons fait représenter, on reconnaissait que les os sus-sternaux n'étaient pas regulièrement arrondis, car ils sont un peu allongés transversalement et aplatis sur le point correspondant du sternum.

In 1840 King (43), with a brief note, presented a sketch of a pair of episternal bones which came under his observation. In 1843 Knox (45) gave the second detailed description of episternal bones, from a case encountered in his dissecting room, and completely confirmed the findings of Breschet.

The specimen I examined with a good deal of attention, but found little to add to the extremely accurate descriptions of preceding observers. Situated behind the sternal attachments of the sterno-mastoid muscles, and mesially in respect to the articular surface for the clavicles, the presternal bones are attached by their bases to the inner or deeper margin of the notch of the manubrium of the sternum; they are of a pyramidal form, and approach each other slightly at their summits. The base of each appeared to me encrusted with cartilage, and there existed a close but distinct movable joint, with a synovial apparatus, and strong ligamentous bands of a peculiar reddish colour, between them and the sternum; one was less movable than the other and a ligamentous band connected them to each other. A few muscular looking fibres, but extremely short, ran from the sternum to these bones.

After Knox the authenticity of Breschet's original descriptions seemed established and subsequent workers became concerned with the homology, embryology and incidence of the episternal structures. Additional careful descriptions of the ossicles and their anatomical relationships and attachments have been furnished by Luschka (52, 53), Carwardine (17), Anthony (4), Lickley (50), Stein (78) and Dixon (22). Following Breschet, dissection of suprasternal cartilages was reported by Luschka (53), Ruge (75), Carwardine (17), Mackay (55), Paterson (66), von Eggeling (25) and Lickley (50). Variations of the ossicles observed on recent and dry material have been described by Luschka (52), Strauch (80), Carwardine (17), Bogusat (9), Paterson (67), von Eggeling (26) and Malaguzzi-Valeri (56). A long series of comparative and embryological investigations seems finally to have shown that the suprasternalia are rudiments of the epicoracoids of the primitive shoulder girdle, other interpretations having considered them respectively; rudiments of the furcular clavicle of Birds (8); the ventral ends of cervical ribs (12, 75, 2, 10); the interclavicle or episternum of lower Vertebrates (28, 26, 10); cartilage separated from the end of the clavicle (30, 34, 37, 47); a clavicular epiphysis (20); a sternal epiphysis resulting from accessory centres of ossification (72, 54); sesamoids (4); and remnants of the precoracoid (17, 50). Only the studies of Strauch (80), Bogusat (9), Paterson (67), von Eggeling (24) and Barchielli (5), have been concerned with the incidence of episternal bones. Lossen and Hofer (51) demonstrated the ossicles in the living in a roentgenogram of a male of 50 years. The monograph of von Eggeling (25) is the most comprehensive treatise on the subject.

Descriptions

Luschka described three cases of episternal bones. Their general form resembled a pisiform with a free convex upper surface and a flattened under surface for articulation with the sternum. One specimen, however, presented four distinct surfaces. The largest ossicle observed had a height of 8 mm. and a breadth of 12 mm. The bones were regularly situated on the hinder portion of the superior manubrial margin adjacent to the clavicular notches. On each manubrium somewhat posteriorly projecting bony elevations with flat or slightly convex free surfaces served as pedestals for the articulation of the suprasternal bones. The ossicles were composed of cancellous tissue surrounded by a thin layer of compactum. They were invested with a relatively thick firmly adherent fibrous periosteum which filled the space between a pair of ossicles. Articulation with the manubrium was by diarthrosis or synchondrosis, the latter being more frequent. Luschka described two ligaments as being peculiar to the suprasternal bones: an anterior ligament which passed from the ventral edge of the semilunar notch obliquely upward and backward to the upper limit of the anterior surface of the suprasternal bone, and a shorter, narrower and vertically directed posterior ligament which joined the dorsal surface of the ossicle to the manubrium (cf. Carwardine). In addition the ossicles were found to be united with the interarticular disc of the sternoclavicular joint by a strong ligamentous mass. Luschka particularly emphasized that neither the interclavicular ligament, the anterior and posterior sternoclavicular ligaments, nor the sternomastoid muscles had any special connection or association with the suprasternal bones.

Eine ganz besondere Berücksichtigung verdient das Verhältnis der Nachbarteile zu den Suprasternalknochen. Hier ist vor allem der Zwischengelenksknorpel des Sternoclaviculargelenkes, welcher eine nahe Beziehung zu jenen Knochen zeigt, indem er durch eine sehr feste Bandmasse mit dem äusseren Umfange derselben in Verbindung steht, resp. an sie befestigt ist.—Das Lig. interclaviculare steht in keinerlei Beziehung zu jenen Knochen, indem es, durch ein straffes Bindegewebe von ihnen geschieden, über sie hinweggeht. Auch das vordere und das hintere Verstärkungsband des Sternoclaviculargelenkes haben nichts mit ihnen zu schaffen, da sie nach aussen vor denselben sich ausbreiten. Ebenso findet sich, dass die Mm. sternocleidomastoidei nicht die entfernteste Beziehung zu den Ossa suprasternalia haben, indem dieselben mindestens 6 mm. nach vorn von ihnen, unter dem vorderen Rande des oberen Brustbeinausschnittes ihre Insertionen finden.

Later, elaborating, Luschka stated that the rather weak fibrous band linking the meniscus to the medial side of the clavicular incisure is notably thickened in the presence of suprasternal bones, and that beneath the interclavicular ligament are found ligamentous bands which bind the episternal bones to each other.

Both Breschet and Knox had mentioned ligamentous connexions of episternal bones to each other without reference to the normal variable interclavicular ligament. Bardeleben (7) later made a study of the interclavicular ligament on preparations from human embryos, foetuses, children and

adolescents. He concluded that the interclavicular ligament of the growing child splits in a characteristic manner. A superficial fibrous band connects the clavicles and a deeper layer runs partly between the menisci but especially between the menisci and the upper manubrial border. He termed the former the Lig. interclaviculare and the latter deeper layer the Lig. episternale. Bardeleben thus recognized the same elements described by Luschka.

Carwardine further elaborated the account. He described a case showing a well-marked T-shaped interclavicular ligament, beneath the horizontal limbs of which two ligamentous bands passed, "from behind the clavicles in a direction forwards, inwards, and downwards to the sternum, where they are attached on either side of the suprasternal notch". These bands he called "suprasternal ligaments". In this case the ligament on the right side was occupied by a suprasternal bone which was freely movable upon an articular facet on the sternum. The joint had a synovial membrane and an articular capsule formed by the fibres which bound the ossicle to the sternum. The corresponding ligament on the left side contained no bone but a slight cartilaginous thickening in its lower part.

In a second specimen Carwardine found the suprasternal ligament on the left side, "passing into an irregular scale-like nodule of bone which [showed] undoubted traces of secondary connexion with the sternum by ankylosis. This suprasternal nodule is in fact a suprasternal bone, which, though at an early period independent, has fused with the sternum at a later stage. On the right side the ligament [passed] into a tubercle representing a similar, but more advanced condition, and which, in order to adopt uniform nomenclature may be called the suprasternal tubercle." From this and one additional case showing suprasternal ligaments but no ossicles or tubercles, Carwardine concluded that suprasternal bones occurred as ossifications in the "suprasternal ligaments", which are almost constantly present in the adult; that the suprasternal bones may fuse early with the sternum and be represented by tubercles with the suprasternal ligaments attached to them; and that in other cases the episternal bones may be incorporated in the manubrium as separate centres of ossification leaving the suprasternal ligaments attached to the sites of incorporation. Carwardine regarded the occurrence of separate ossicles as a sign of incomplete ossification and development of the sternum.

Anthony noted, nearly always, the suprasternal ligaments described by Carwardine and sometimes the accompanying suprasternal tubercles mentioned by the latter:

> Voici, d'après une de nos observations, la description de cette anomalie; c'était chez un homme de 41 ans (un seul cas sur 66 dissections). La fourchette sternale présentait à ses deux extrémités deux petits noyaux osseux de la grosseur d'un pois à peu près et ayant la forme d'une pyramide triangulaire. Ils présentaient quatre faces: une inférieure, une externe, une antérieure et une postérieure. La face inférieure s'articulait avec le sternum; la face externe avec le cartilage inter-sterno-claviculaire; ces articulations étaient des diarthroses (dans un cas de Luschka l'os suprasternal se reliait au sternum par synchondrose). La petite cavité de l'articu-

lation sterno-suprasternale communiquait en avant seulement avec l'articulation sterno-meniscoidale; la cavité de l'articulation suprasterno-meniscoidale communiquait en arrière seulement avec celle de l'articulation sterno-meniscoidale; la face antérieure était recouverte par quelques ligaments longitudinaux partant du ligament interclaviculaire pour se rendre au sternum. Ces ligaments sont ceux sur lesquels s'étend Carwardine. En outre de cela quelques fibres parallèles à celles du ligament interclaviculaire reliaient l'os suprasternal à la clavicule. La face postérieure était en connexion avec le sternum et la clavicule par l'intermédiaire de fibres irregulièrement disposées mais suivant, pour la plupart, la direction du ligament interclaviculaire. Des quatres angles deux seulement présentaient des particularités dignes d'intérêt: l'angle supérieure qui se reliait au ménisque interclaviculaire et à la clavicule par des fibres parallèles au ligament interclaviculaire, et l'angle interne qui donnait attache à des fibres dont la direction était la même que celle des précédentes; de ces dernières fibres les unes s'attachaient au sternum, les autres se perdaient dans l'épaisseur du ligament interclaviculaire. Chose importante à noter, c'est que l'os suprasternal n'affectait que de simples rapports de contiguité avec le ménisque interarticulaire.

This case presented also an articulation in the middle of the xiphisternum and a presternal (sternalis) muscle.

The subsequent careful description of the relationships of episternal bones by Lickley gave essential confirmation to ligamentous arrangements reported by Luschka, Bardeleben, Carwardine and Anthony. Because Lickley's is perhaps the most photographic of the accounts it is presented *in toto* to afford comparison with the more diagrammatic descriptions of other writers:

With the upper margin of the presternum, between the clavicular articular surfaces, two bones, about the size of large pisiform bones, articulated. The articular surfaces for these bones occupied the greater part of the interclavicular notch, only a small median notch being non-articular. Each articular surface was oval in outline and nearly flat both from side to side and from before backwards.

The bones were firmly held in position by ligaments. The interclavicular ligament occupied its usual position between the sternal ends of the clavicles. From its deep surface a fibrous sheet passed down to the anterior surface of the presternum. This ligamentous sheet was specially strengthened over the anterior surface of each suprasternal bone, the whole ligament presenting therefore the appearance of two strong lateral bands with a thinner intervening portion. A thinner band passed down from the interclavicular ligament behind the bones to be attached to the posterior surface of the presternum. Traced outwards these ligaments were found to become associated with the capsule of the sternoclavicular articulation and with the anterior and posterior sternoclavicular ligaments.

The bones themselves were bound to one another by strong interosseous fibres extending between their mesial surfaces across the middle line. In addition each bone was attached to the corresponding fibroplate of the sternoclavicular joint by means of ligamentous bands passing downwards and outwards.

The presence of two cartilaginous nodules corresponding in position with these bones was noted in another case also. The sternum was taken from a girl of 18 whose general development was very defective. At the sides of the interclavicular notch were two distinct cartilaginous nodules—that on the right being the larger, each articulating with the upper margin of the presternum, and connected to it by a capsule of fibrous tissue.

Stein described a case in which the outer surface of each episternal bone was united to the interarticular disc of the sternoclavicular joint by a fibrous mass.

Dixon reported two cases, one in an adult man, the other in an adult woman. His roentgenograms showed that the architecture of the suprasternal bones resembled that of the sternum. In the male the ossicles were of conical form, large and almost symmetrically placed; those of the female were somewhat pea-shaped and placed close against the median plane. The ossicles of both male and female articulated with the sternum by diarthrodial joints. In the female there was also a diarthrodial joint in the median plane where the right and left ossicles were in contact. The capsular ligaments of the bones in the male were loose enough to permit considerable movement at the articulations. Each suprasternal ossicle of the female was "tied down to the sternum by a well-defined fibrous capsule which is specially thickened on its anterior aspect to form a rounded cord-like ligament. The anterior surfaces of the ossicles were connected by a fibrous band, the upper margin of which was continuous with the interclavicular ligament. Laterally each was connected to the clavicle by a fibrous cord, the lower and lateral edge of which was continuous with the sternoclavicular ligament." Dixon emphasized that "the suprasternal bones are not directly connected with the fibro-cartilaginous disc, and that the joints which they form with the sternum are distinct and isolated from the clavicular articulations".

In considering Dixon's failure to find the special fibrous or ligamentous connexion between meniscus of the sternoclavicular joint and suprasternal bone or cartilage reported by Luschka, Anthony, Lickley, von Eggeling and Stein, it is to be remembered that the ossicles are really embedded in a fibro-ligamentous mass of which the structural elements may be variously determined by different dissectors.

Episternal bones are preformed in cartilage. Episternal cartilages were first described by Breschet from specimens in an adult. A pair were found by Luschka in an 11-year-old boy. They were of hyaline material, with a breadth of 5 mm. and a height of 4 mm. The attachment to the sternoclavicular meniscus was clearly marked. Ruge found episternal cartilages in a male infant of 6 months, illustrated by his fig. 22. They exhibit the same form and positional relationships as the adult ossicles.

In 290 foetal sterna between 3 and 9 months, Paterson (66) found two examples of suprasternal cartilages. Upon the upper border of one female sternum of 6 months two ovoid cartilages were present, fused to each other but separate from the manubrium. On a second female sternum of 9 months two cartilages occurred, separate from each other but fused with the upper manubrial border. Mackay (55) demonstrated cartilaginous suprasternal nodules in three cases of foetal sterna of the seventh month. The cases of Carwardine and Lickley have been mentioned. von Eggeling (25) described three cases of suprasternal cartilages. In a girl of $3\frac{1}{2}$ years small hyaline suprasternal cartilages were found which did not extend to the clavicular articular surfaces. They were bound by fibrous bands to a cartilaginous manubrium. A boy of $4\frac{1}{2}$ years presented asymmetrical hyaline cartilages which were contiguous laterally

with the clavicular incisurae. The ossification of the manubrium was almost complete. A right unilateral cartilage occurred in a boy of $12\frac{1}{2}$ years which did not reach the clavicular notch. Sections of the cartilage revealed a centre of ossification. This is the earliest age at which a calcified nodule has been reported. In a study of the ossification of the sternum embracing 450 specimens of which 31 were foetal, 68 newborn, and the remainder ranging up to 16 years, Markowski did not report a single case of suprasternal cartilages.

The most remarkable of the variations of suprasternal bones is their occurrence as nodules of bone fused to the superior manubrial border which alter the character of the jugular notch. This relationship between the contour of the upper margin of the manubrium and suprasternal bones was first perceived by Luschka (53). He stated that in addition to normal variation as to size and form, the semilunar notch manifested a great variability because of the existence of suprasternal bones. While the most common form of jugular notch presented a concave rounded margin which was steep behind and sloped forward gradually, there would frequently be found on the highest posterior part of this margin, on either side, inconspicuous rounded rough eminences which according to the breadth of the notch either directly adjoined the clavicular incisurae or were separated from them by a deeper intermediate area. Often, especially on the narrower semilunar notches, there occurred in the position of these inconspicuous elevations discrete projecting bony processes which sprang up between the semilunar notch and the highest point of the clavicular notch. These processes or tubercles were attached to the sternoclavicular menisci by short bands of fibres and were held by Luschka to be undoubtedly manifestations of suprasternal bones. An interpretation was later made independently by Carwardine as has been seen.

Die Grösse und die Gestaltung der Incisura semilunaris zeigt schon innerhalb des Breitegrades der Normalität bedeutende Schwankungen und besitzt bei der Existenz von Suprasternalknochen einen sehr abweichenden Typus. Bei ganz regelmässiger Bildung stellt sie einen konkaven abgerundeten Rand dar, welcher gegen die hintere Seite steil, nach vorn dagegen ganz allmählich abfällt.—Gegen sein Ende geht der erhabenste Teil dieses Randes jederseits sehr häufig in eine rundlich Rauhigkeit über, die jedoch ihrer Flachheit wegen die Aufmerksamkeit kaum auf sich zieht und, je nach der Breite der Incisura, entweder mittelbar an den Schlüsselbeinausschnitt angrenzt oder durch einen schmalen, etwas vertieften Zwischenraum von ihm geschieden ist.—Nicht finden sich, zumal bei schmaler Incisura, an den Stellen dieser unscheinbaren Erhebungen grössere, durch ihre Höhe und durch ihren Umfang sehr augenfällige, rundliche Knochenvorsprünge, welche sich hügelartig zwischen der Incisura semilunaris und dem höchsten Punkte des Schlüsselbeinausschnittes erheben.—Diese kleinen oder grösseren Knochenerhebungen nehmen die Aufmerksamkeit dadurch in Anspruch, dass an ihnen durch einen kurzen Bandstreifen die Anheftung des Meniscus der Sternoclavicularverbindung statt hat und dass sie ohne allen Zweifel die Andeutungen der unter Umständen als einige Skeletteile auftretenden Suprasternalknochen sind.

In the first statistical study Strauch recognized in his classification separate episternal bones and episternal tubercles. Bogusat found in his series three cases in which episternal bones occurred on one side only. Paterson presented

an excellent plate of ten specimens showing: separate ossicles; a pair of ossicles, one of which was fused and the other separate; suprasternal tubercles; tubercles with articular facets; the suprasternal border raised into a median projection; and normal semilunar incisurae, one broad and shallow, another narrow and deep. He mentioned that the ossicles might be fused together and be bilateral or median in position. Von Eggeling stated that between sterna with fully formed separate ossa suprasternalia and those with no trace of the ossicles there exists a large series of intermediate stages which demonstrates the gradual disappearance of this once prominent skeletal feature. He illustrated with a plate similar to Paterson's but showing some slightly different stages. Malaguzzi-Valeri described with illustrations of roentgenograms two cases of episternal bones, one with a unilateral ossicle, the other with symmetrical bones, one of which was fused and the other free.

Homology

The determination of the phyletic significance of suprasternal bones was a difficult problem because its solution was dependent upon the unravelling of certain of the perplexing homologies of shoulder girdle, sternum and ribs. The approach was through comparative and embryological investigations, both being pursued concurrently by several workers.

Béclard's original suggestion that episternal bones were related to the avian furcular clavicle received no further support. Breschet, and afterwards Bonnet (10), considered them the ventral rudiments of seventh cervical ribs. Ruge (75) also held probable an origin from a seventh cervical rib, although he made no definite commitment. Luschka (53), however, whose study apparently escaped the attention of Ruge, reported a case in which well-developed episternal bones were present on a manubrium which had been joined by a seventh cervical rib below the clavicular articular facet. Lebouc q (47), Ledouble (48), Stein (78) and von Eggeling (26) confirmed this finding with similar cases. Turner (88), Albrecht (2) and Keith and Herkelet (42) also showed that the ventral attachment of a seventh cervical rib was always below the clavicular facets.

Malaguzzi-Valeri (56) agreed that this evidence excluded origin from a seventh cervical rib but suggested that derivation from a higher cervical rib, probably the sixth, was possible because episternal bones are preformed in cartilage and are generally accompanied by cervical ribs and because, like the ventral ends of the latter, they tend to be asymmetrically developed and become incorporated in the manibrium. No positive evidence has rendered this theory tenable. Episternal bones, therefore, could not be considered the rudiments of ventral ends of cervical ribs. They must represent elements of either the shoulder girdle or the sternum.

The sternum itself, however, is now held to be a shoulder girdle derivative, as shown by the ontogenetic and comparative studies of Paterson (67), Kravetz (46), Whitehill and Waddell (90), Hanson (35) and Gladstone and

Wakeley (32). It is formed from the sternal bands and a median anlage cranial to the latter, all of which arise independently of the ribs. As the sternal bands fuse the median anlage is incorporated with them. The suprasternal elements, it now appears, are variable components developed from two additional lateral condensations of mesoderm between the median anlage and the inner ends of the clavicles. The median anlage may be recognized in embryos of from 16 to 22 mm., but not earlier (32).

The anlagen of human suprasternal bones were first described and illustrated by Ruge as two nuclei found in embryos of 24, 25, 30 and 30 mm., cranial to the sternal bands and between the sternal ends of the clavicles. These nuclei were subsequently studied by Müller (60), Malaguzzi-Valeri (56), and Gladstone and Wakeley. Malaguzzi-Valeri contended that the nuclei were not the anlagen of suprasternal cartilages, submitting that the nuclei were constant and the ossicles rare; that the nuclei were never distinctly cartilaginous, while the ossicles were always so preformed; and that the nuclei appeared more closely linked by their structure to the clavicles than to the sternum, but the suprasternalia exhibited affinity to the sternum, often fusing with it.

The other two authors agreed with Ruge in considering the episternal nuclei the anlagen of the adult ossicles. It was the opinion of Müller and of Eggeling, later concurred in by Bardeen (6), that the paired nuclei usually fused with the sternum but might become ossified either separately or as bony projections from the upper margin of the manubrium.

Although Ruge advocated as a result of his investigation his long-accepted theory of a costal origin for the sternum, he was careful to emphasize that the significance of the "episternal" nuclei was not determined, but as previously mentioned he was inclined to regard them as ventral rudiments of cervical ribs.

Gross specimens and dissections have established the constant position of suprasternal bones on the posterior manubrial margin as inclusions in the ligamentous investment of the sternoclavicular joint often especially attached to the interarticular disc of the latter, and have demonstrated that the ossicles are not the ventral rudiments of seventh cervical ribs. Embryological studies have shown that the ossicles develop from an anlage associated with the shoulder girdle. More precise determination of the homology of the ossa suprasternalia must be sought in comparative investigations.

These comprise a large literature which cannot be said to settle the question absolutely, although the evidence clearly indicates a derivation from the epicoracoids or their cranial prolongations, the omosterna. The preglenoid portion of the pectoral girdle is considered to consist primitively of a coracoid bar which by fenestration becomes subdivided into cephalic procoracoid and caudal coracoid bars, joined ventrally by an epicoracoid (39). This condition is illustrated by the snapping turtle, *Chelydra serpentina*. Continuous caudally with the median epicoracoids is the rib-bearing sternum proper, the essential paired nature of which is evident from its formation through the sternal bands.

Cranially from the epicoracoids there may extend cartilaginous prolongations, the omosterna, which, like the costal sternum below, may become fused into one. A well-developed omosternum may be seen in the bull frog, *Rana catesbiana*. Secondarily, the clavicles and the episternum or interclavicle appear as dermal elements. Both are present in the monotreme, *Ornithorhyncus anatinus*. In the duck-bill the prosternum or manubrium articulates with one and a half ribs. Attached cranially to the prosternum, and hence precostal in position, are the primitive elements of the shoulder girdle. The coracoids are firmly joined to the lateral angles of the prosternum. Above the coracoids are large epicoracoids which overlap each other. In the position of the procoracoids are long clavicles which reach from the acromial processes to the mid-line, where they meet. Co-extensive with the clavicles is the horizontal portion of a large T-shaped interclavicle, the broad vertical bar of which overlies the epicoracoids and rests upon the prosternum. The interclavicle is often described as supporting the clavicles. It is thus apparent that in their primitive positions the clavicles are separated from the costal sternum by a wide interval, represented in the cartilaginous girdle by the epicoracoids which extend forward to the procoracoids. Since the membranous clavicle invested or at least replaced the procoracoid, the same distance is spanned by the vertical portion of the membranous interclavicle. In the higher Mammals, however, the clavicles have come to articulate directly with the sternum just cephalic to the attachment of the first rib. The fate of the primitive elements intervening between clavicles and costal sternum, namely, procoracoid, epicoracoid and interclavicle, is the problem which long intrigued morphologists.

Between the primitive condition in the monotreme and the advanced arrangement in Man are certain intermediate conformations in which the clavicles do not directly articulate with the sternum. These are found in Marsupials, Edentates, Insectivores, Rodents and lower Primates, animals which are either primitive, as the Marsupials, or have extensive use for the upper extremity in burrowing or brachiating. Examples of most of these forms are figured in Parker's comprehensive monograph on the shoulder girdle.

The elements which intervene between clavicles and sternum of the monodelphia mentioned are the T-shaped Marsupial episternum and the praeclavia of Rodents and Insectivores. As both of these elements are preformed in cartilage, the membranous interclavicle may be dismissed at once as a possible precursor. Although Nauck (61) has recently claimed that the interclavicle of Monotremes is in reality, like the clavicle, a mixed bone formed through fusion of the dermal interclavicle and part of the primordial cartilaginous prosternum, the monotrematous interclavicle has both topographically and functionally the same relationships as that of the saurian. The interclavicle is in relation with the anterior or ventral surface of the costal prosternum, while the praeclavia and suprasternalia are in relation with its posterior or dorsal surface. Parker held that the saurian interclavicle was not represented in Mammals

above the Monotremes. Broom (13) described the loss of the interclavicle as a change to give the clavicles greater mobility, as the median detachment of the coracoids afforded greater freedom of movement to the limbs.

The possible precursors of the ossa suprasternalia are thus reduced to medial procoracoid, cranial epicoracoid or its adjacent forward prolongation, the omosternum.

In the opossum, *Didelphys marsupialis*, Gegenbaur found a small T-shaped cartilaginous structure which he called the "episternum". The clavicles articulated with the lateral bars of the T. These portions Gegenbaur homologized with the praeclavia of Rodents and the human interarticular disc. The middle piece of the T he considered represented by human episternal bones. Parker directed attention to a distinct fibrous tract which separated the middle piece of the T interpreted by him as prosternum from the arms (omosternum). The homology of this middle piece is uncertain. Götte described in the embryo mole a cartilaginous T-shaped episternum formed of paired median bars which lay ventral to the manubrium and extended forward to articulate with two lateral bars for the clavicles. This cartilaginous structure in the position of the membranous interclavicle was held by Gladstone and Wakeley to represent in the lateral bars, the articular cartilages between the omosterna (praeclavia) of the mouse and the interarticular disc in Man, and in the median paired elements, the omosterna. How the latter authors explain the position of Götte's median bars as omosterna *ventral* to the manubrium is not clear.

Among the Edentates Luschka found in the six-banded armadillo, *Dasypus sexcinctus*, a small bone on each side through which the clavicles articulated with the sternum. In the nine-banded armadillo, *Dasypus novemcinctus*, he found a single bifid skeletal element at the cephalic end of the sternum, the prongs of which furnished attachment for the clavicles. The latter condition Luschka thought anticipated the former, and he considered the praeclavia of *Dasypus sexcinctus* the homologues of suprasternal bones.

The praeclavia of Rodents and Insectivores present great variability but all are in relation with the posterior aspect of the superior portion of the manubrium (prosternum), and some pairs overlap in the mid-line.

The investigation of Oehngren (62), who studied foetuses of several species of Insectivore, is perhaps most illuminating. In these animals the episternalia or praeclavia connected the clavicles with the sternum. The episternal structures occupied the dorsal position just described in relation to the manubrium and were considered by Oehngren the homologues of the human suprasternalia. This author pointed out that the overlapping of the episternal elements in *Microgale dobsoni* was directly comparable to the overlapping of the epicoracoids in certain Amphibia (*Anura arcifera*), in which the epicoracoids occupied a similar position in relation to the sternum.

It may be accepted, therefore, that the praeclavia are homologues of the epicoracoids, and there remains to be established only the relationship between the praeclavia and suprasternal bones. Luschka, Eggeling and others have

considered with Oehngren that the suprasternal bones and praeclavia are homologous. This phase will be treated further in the discussion below.

Among the Primates, Burmeister's illustration of a skeleton of *Tarsius* shows well-developed episternal ossicles (16). There is no comment in the text. Parker gives figures of the praeclavia of *Mycetes seniculus* and *ursinus*. The suprasternalia are known to occur in *Cercocebus aethiops* and *Pithecus satyrus* (25).

Due apparently to misunderstanding of the nature of an epiphysis, Dawson (20) recently suggested that the praeclavium of the rat, *Mus norvegicus albinus*, was homologous with the sternal epiphysis of the clavicle instead of the epicoracoids. Parker had previously represented the praeclavium of *Mus musculus* as the omosternum which itself he derived from the epicoracoid.

A clavicular origin for the suprasternalia had been postulated before, however, for Gegenbaur (30), Götte (34), and Hoffmann (37) construed them to be derived from cartilage separated from the end of the clavicle. But even if this were true the clavicular cartilage according to present concepts would have to represent a procoracoid source.

Brief mention may be made of certain other suggestions on the derivation of episternal bones. Rambaud and Renault (72) stated that they had never found the suprasternal bones described by Breschet. They described and illustrated separate sternal epiphyses for the clavicular articular facets and suggested that these plaques might be the suprasternal elements despite the obvious totally different form and position of the two. Secondary centres of ossification for the clavicular facets are mentioned also by Radasch (71). Curiously enough, Macalister (54) wrote, "Thin crusts of epiphyses appear on the clavicular surfaces about the age of twenty-five and soon become united", but his illustration of these crusts plainly showed well-developed suprasternal bones.

Later Rambaud and Renault described as sesamoids two ossicles which were true suprasternal bones. They held that these sesamoids were the suprasternalia.

Anthony at first regarded the suprasternal bones as rudiments of the epiprecoracoids. He later changed this view and interpreted them, "comme des sésamoides d'apparition récente chez un animal où les mouvements de la clavicule sur le sternum ont acquis leur maximum de liberté et où, par le fait de la disposition même des parties, les frottements atteignent une grande intensité". The sesamoid theory is hardly to be entertained seriously, however, for the ossicles do not occur in the tendon of any muscle, and their location is not the site of particular functional stress. Neither do they by their presence appear to strengthen, protect or functionally improve the sternoclavicular joint.

The evidently erroneous concept that suprasternal bones might be represented by accessory centres of ossification in the manubrium beneath the sites attachment of the suprasternal ligaments was introduced by Carwardine. His Fig. 4 shows two such centres above the usual single large centre for the manu-

brium. Unlike the accompanying diagrams, however, this figure did not illustrate an actual case. It was a hypothetical diagram based on the account of Breschet. Examination of Breschet's original article does not reveal justification for it. This author merely admits that the sternum may be formed from two series of laterally placed nuclei.[1] After his extensive investigation of the subject Paterson concluded that centres of ossification in the sternum were of no essential morphological importance. The centres hypothetically introduced by Carwardine were not found in the series of young sterna studied by Anthony, Mayet (59) or Markowski, and in so far as we have been able to determine they have never been found to exist.

Incidence

Only the investigations of Strauch (80), Paterson (67), Bogusat (9), von Eggeling (24) and Barchielli (5) have been concerned with the incidence of episternal bones. Of these the latter three also gave attention to the form of the superior border of the manubrium.

In 200 sterna at Dorpat, Strauch found 4 cases (2 per cent.) with distinct episternal bones on both sides and 1 case (0·5 per cent.) with one ossicle. He noted only 6 cases (3 per cent.) with suprasternal tubercles.

Out of 563 sterna of various ages in Liverpool, Paterson found only 1 case bearing a pair of separate suprasternal ossicles. In another case he noted a pronounced tubercle on one side and a sessile prominence on the other, surmounted by an articular facet. In 45 cases (8 per cent.) there were found on the suprasternal border two lateral projections in the form of ridges or tubercles, sometimes provided with articular facets. In 51 cases (9 per cent.) there was a tendency toward the formation of a single median protuberance in place of the notch. The remaining 467 sterna were classed as possessing a normal suprasternal notch.

Bogusat, at Königsberg, found 3 unilateral episternal bones on 120 sterna (2·5 per cent.). Episternal tubercles were not mentioned.

Von Eggeling classified his Strassburg material in a manner similar to that of Paterson. In a series of 226 sterna, from which 5 were eliminated for pathological reasons, von Eggeling found 3 cases (1·35 per cent.) with suprasternal bones on both sides. Six cases (2·7 per cent.) had a separate ossicle on one side. Twenty-one specimens (9·2 per cent.) showed suprasternal tubercles. Fifty-three sterna (24 per cent.) had a flat or projecting upper border and 144 (65 per cent.) presented the normal jugular notch.

Von Eggeling divided his sterna into four ill-defined and overlapping groups for consideration of the superior manubrial margin. His first group was characterized by a jugular notch, of which he illustrated deep, shallow and

[1] Breschet, p. 101: "Les petites pièces osseuses, que nous signalons ici, peuvent-elles être données comme une preuve du mode de développement du sternum, par deux noyaux latéraux, et confirmer la loi de symétrie de l'ostéogénie, proposée par M. Serres?" P. 103: "...nous admettions la formation du sternum par deux séries de noyaux osseux latéraux."

narrow varieties. The second group was marked by a jugular crest, or practically horizontal upper manubrial border. The third group was distinguished by jugular tubercles. These were low rather poorly delimited eminences of which two types were described. In one the tuber was confluent with the margin of the clavicular notch; in the other it was separated from the latter by a furrow. Von Eggeling seems to have regarded the tubera as rudiments of the suprasternalia. The fourth group had ossa or tubercula suprasternalia. Von Eggeling stated that Markowski's figures showed that all these types were preformed in cartilage. The writer, however, was unable to find in Markowski's plates, which showed 180 young specimens, a cartilaginous border which had a tuber jugulare separated from the clavicular notch. The significance of this will be discussed below.

Von Eggeling directed attention to a horizontal line often distinctly visible on the posterior manubrial surface which extended between indentures in the clavicular facets and demarcated the precostal from the costal portion of the manubrium.

In 162 adult sterna Barchielli (5) found no cases of separate episternal ossicles, 3 cases (1·7 per cent.) of episternal tubercles, 3 cases (1·7 per cent.) in which the superior manubrial margin was prolonged to a point, 4 specimens (2·5 per cent.) in which this border was convex, 43 specimens (26·5 per cent.) which exhibited a straight border, and 109 (67·2 per cent.) showed the normal incisura jugularis. This author affirmed that the ossa and tubercula suprasternalia represented the ossified suprasternal cartilages free and fused with the sternum respectively, and that the various forms of convex and straight upper manubrial border represented the episternal elements fused to each other and with the sternum but incorporated in the latter to different degrees.

Thus, our knowledge of the incidence of episternal bones is limited to the results of studies of five small series of sterna of different European nationalities comprising a total of 1270 specimens. The illustrations and descriptions of the several investigators have provided an illuminating but incomplete picture of the range of variability of the ossicles.

Von Eggeling alone has presented a table showing the age and sex distribution of his material, but the series and total number of ossicles (9) and tubercles (15) found is too small to give reliable estimates of incidence.

The statement appears in Wilson's *Anatomy* (33) that suprasternal bones appear in about the thirty-eighth year. Hutchinson (40) states that they occur only at rather advanced periods of life. Von Eggeling's previously mentioned find of a centre of ossification in a suprasternal cartilage of a boy of $12\frac{1}{2}$ years is the earliest osseous appearance reported. He found suprasternal tubercles in a male and a female subject between the fifteenth and twentieth years.

The racial incidence of the suprasternalia has not been investigated. Because his Strassburg material showed a much greater incidence than Paterson's Liverpool series, von Eggeling suggested that it was highly probable that different anthropological groups would show varying percentages of the ossicles.

Carwardine and Lickley associated the occurrence of episternal bones with defective osseous development in the sternum or elsewhere. Leboucq and Malaguzzi-Valeri emphasized their occurrence in association with cervical rib, Leboucq interpreting the phenomenon to be a separation of skeletal elements normally fused together.

There are numerous additional scattered comments on the form of the upper manubrium. Portal (70) stated that with a highly hafted shoulder there is usually a low clavicular notch probably due to pressure of the clavicle on the sternum. Dursy mentioned that occasionally the clavicular notches are approximated at the expense of the jugular notch. Aeby (1) observed that the superior manubrial margin may be raised up into a prominent oblique eminence. Pansch (64) noted that the lateral end of the jugular notch frequently presented elevations of varying form and size, some of which resembled fused suprasternal bones. His Fig. 2 shows such a case in which the meniscus of the sternoclavicular joint was attached to the lateral side of the process. Poirier remarked upon the varying breadth and depth of the jugular notch and stated that occasionally it terminated in a roughened region corresponding to the attachment of the superior sternoclavicular ligament. Von Eggeling is particular to point out that the functional use of the upper extremity is the essential factor determining the structure of the shoulder girdle, a fact which must be kept in mind in considering the form of the manubrium. Kirchner gave the dimensions and incidence of manubrial types in 27 sterna studied at Gottingen, but this series is too small to be seriously considered to-day.

III. MATERIAL AND METHOD

The human skeletons of the Hamann Museum collections have been obtained almost entirely from laboratory cadavera. The manner of documentation and preservation, and the demographic characteristics of this skeletal population have been repeatedly described (84, 86). A brief review of these has recently appeared (18). It will suffice at present to cite that for each individual, sex, race, and in most cases, age and birthplace or nationality are known. The whites are chiefly European immigrants or their immediate descendants. The Negroes are mostly industrial migrants from the south. Analysis has shown that this laboratory group presents less evidence of hybridization than the American Negro as a whole (86). The sex, age and racial distribution of the sterna used in this study are furnished in Table IX. The anthropoid sterna were from animals secured in their native habitats.

The roentgenograms and dry bones of Series I were studied first. The dissections were made after the specimens had been roentgenographed. This experience furnished the background necessary for the classification of the specimens in Series II which consisted of bones only. Here often the presence of suprasternal articular facets was accepted as reliable evidence of the existence of separate ossicles which had been lost.

The drawings of Figs. 1 and 4 were traced in outline from the roentgenograms and embellished from observation of the actual specimens. The superior aspects of the upper manubrial margins seen in Fig. 3 are camera lucida drawings of the bones themselves.

IV. RESULTS OF THE STUDY AND DISCUSSION

The results of the study of Series I and II are presented in the figures and tables. The findings from Series III and the dissections are incorporated in the discussion.

Variation

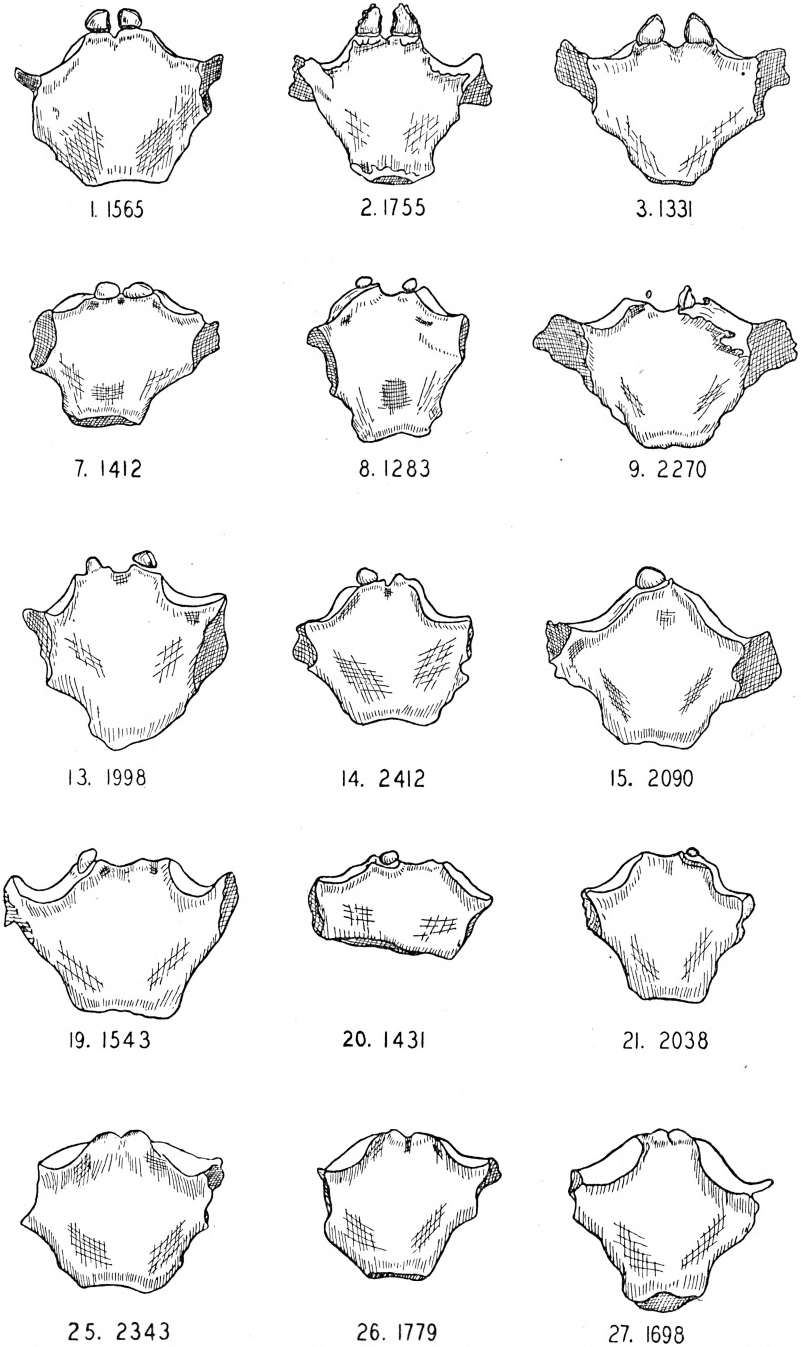
The specimens of Figs. 1 and 2 illustrate the variation of suprasternal bones in size, form, position and integrity. They may occur in pairs or singly. They may be separate, forming a diarthrodial joint with the manubrium complete with articular cartilage and synovial membrane; they may be united to the manubrium by fibrocartilaginous synchondrosis; or as small nodules they may be ensconced within the suprasternal ligaments and have no contact with the manubrium (Fig. 1, no. 9).

The ossicles may exhibit various degrees of fusion with the manubrium and with each other, almost complete incorporation in the former being sometimes detectable (Fig. 1, no. 26). No case was found in which the ossicles had fused with each other but not with the manubrium, although such a case has been reported by Paterson (67).

Paired suprasternal bones may be of subequal size and symmetrical form and position on the manubrium (Fig. 1, nos. 1–4), or of unequal size and asymmetrical arrangement (nos. 9, 10). One element may be separate and the other fused (nos. 11–14).

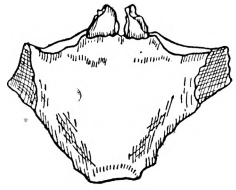
Size. Suprasternal bones range in size between that of a small shot and an average female lunate bone. The smallest specimen (Fig. 1, no. 9, left) had a height of 4 mm. and a breadth of 2·25 mm. (measured on the roentgenogram). The largest in our series, from cadaver No. 2549, measured 13·5 mm. in length (antero-posterior), 19·5 mm. in breadth, and 10 mm. in height. This slightly exceeds in size the largest specimen previously recorded, which was described by von Eggeling as having a length of 20 mm., a breadth of 11 mm. and a height of 6 mm. Inspection of Fig. 1 readily indicates that a mathematical average size would have little value because of the range and amount of variability, hence the dimensions of 19 separate ossicles of various sizes are presented in Table I.

Form. In the shape of suprasternal bones there is manifest a characteristic basic pattern, a fact which the wide variations in size, symmetry and sharpness of form tend to mask. In its full expression the fundamental pattern is an irregular pyramid with a base, four surfaces and an apex. This is best illustrated in our series by the specimens from No. 1440 (Fig. 2, no. 1). The relationships of the surfaces in the recent state will shortly be described.

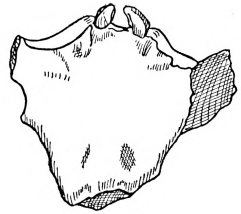


N.B. The subscribed number of all figures is the file number of the skeleton in the Hamann Museum.

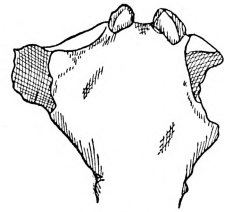
Fig. 1. Variation of suprasternal bones. Nos. 1–10, paired separate ossicles; nos. 11–14, paired ossicles, one separate, one fused; nos. 15–23, single separate ossicles; nos. 24–27, 30, paired fused ossicles; nos. 28, 29, single fused ossicles.



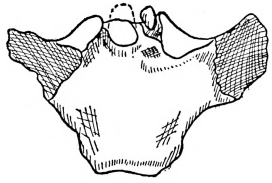
4. 1440



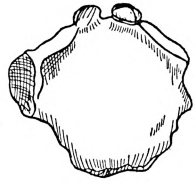
5. 2294



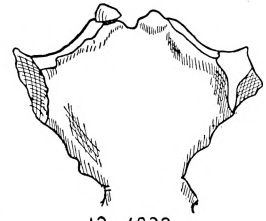
6. 1246



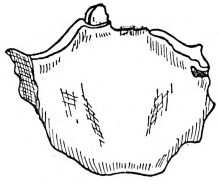
10. 2296



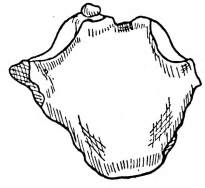
11. 1813



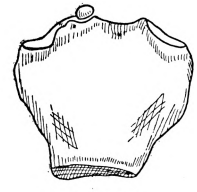
12. 1832



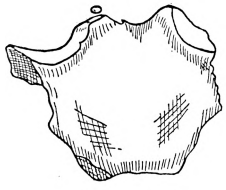
16. 1892



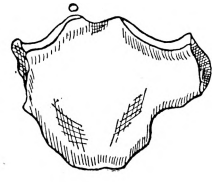
17. 1962



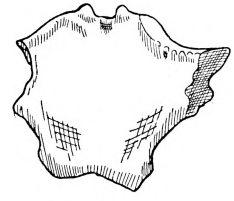
18. 1809



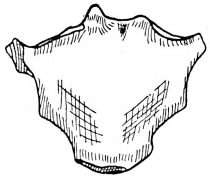
22. 1609



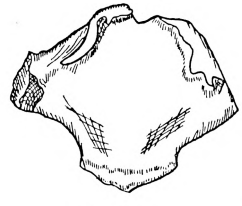
23. 1610



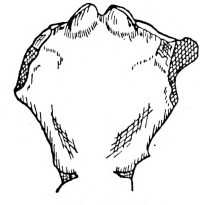
24. 1500



28. 1928



29. 2251



30. 2244

Fig. 1 (*continued*).

The base may be flat with a slight downward projection at the postero-lateral angle, but is usually more or less concave from before backward so as to grip the manubrial surface and in diarthrodial joints permit slight gliding motion. The borders of the base correspond to the surfaces of the ossicle.

The four typical surfaces, anterior (ventral), posterior (dorsal), medial and lateral are represented diagrammatically in Fig. 2. They are separated by borders which converge from the base upon the apex and may be termed respectively antero-medial, antero-lateral, postero-lateral and postero-medial.

Of the surfaces the lateral is the most constant, often the largest, and the medial the smallest and most variable. The more vertical anterior surface is regularly narrower than the sloping convex posterior surface. A similar relationship exists between the narrower more vertical medial surface and the

Table I. *Dimensions of suprasternal bones*

No.	Cadaver No.		Length (antero-posterior) mm.	Breadth mm.	Height mm.
1	2549	R.	13·5	19·5	10·0
		L.	16·25	11·0	10·0
2	2710	R.	9·75	13·0	8·0
		L.	11·5	13·0	7·5
3	1331	R.	10·5	11·5	9·0
		L.	11·0	11·25	9·5
4	2705	R.	9·75	13·0	8·0
		L.	11·5	13·0	7·5
5	1440	R.	11·0	10·0	8·75
		L.	11·0	11·75	8·0
6	1246	R.	12·0	12·5	7·0
		L.	11·0	10·0	7·0
7	2270	R.	12·0	7·0	7·0
		L.	(X-ray)	2·25	4·0
8	1283	R.	6·0	6·5	3·75
		L.	5·25	6·0	3·5
9	1813	R.	11·0	13·0	8·0
		L. (f.)	10·5	9·75	8·0
10	1610	L.	3·5	4·0	3·0
		Average	10·4	10·4	7·3

broad lateral surface which has topographical continuity with the adjacent clavicular notch of the sternum.

The apex is usually definitely recognizable. It is most frequently rounded (Fig. 2, no. 2), but may be flattened (no. 5), or compressed into a sharp or rounded ridge extending either medio-laterally (no. 3), or antero-posteriorly (no. 6). The differences in the relations and sizes of the surfaces associated with the several types of apices are shown by the diagrams of Fig. 2.

The most common variant from the pyramid with quadrangular base is represented by Fig. 2, no. 2, in which the base is triangular, the medial surface here being reduced to a broad rounded border. This may be termed the medial border and be considered to represent the confluence of antero-medial and postero-medial borders.

In even the small decidedly rounded ossicles (Fig. 1, nos. 8, 23) this triangular pyramidal form may be clearly distinguished, especially with

the aid of a hand lens. The antero-posterior elongation seen in the specimen from No. 2270 (Fig. 2, no. 6, right), resulting in elimination of anterior and posterior surfaces is rare. In the specimens of Fig. 2, no. 4, each anterior and the left lateral surfaces have become subdivided by secondary ridges.

In ossicles fused or partially incorporated with the manubrium both four (No. 825) and three (No. 1507) sided pyramidal shapes may be distinctly recognized, the latter being the more common. The quadrilateral form is usual in paired ossicles which are fused to each other as well as the manubrium.

Viewed *in situ* from behind, the silhouettes of well-developed suprasternal bones resemble right triangles of which the bases rest upon the manubrium and the hypotenuses form the lateral borders, the medial borders approaching

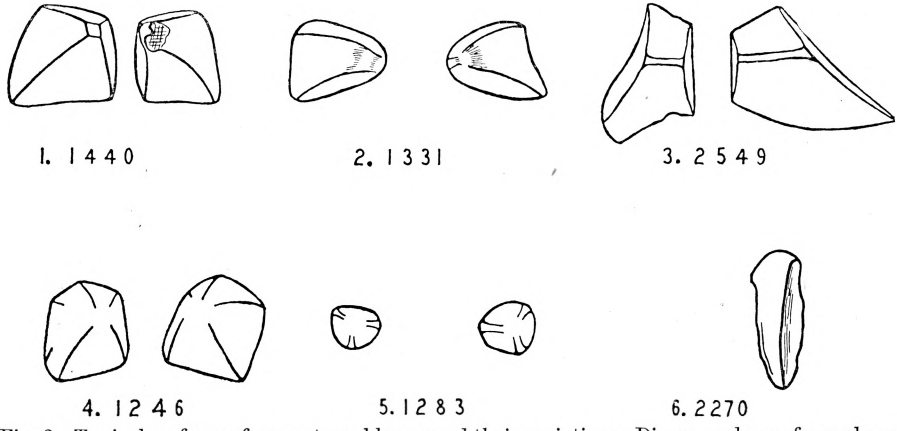


Fig. 2. Typical surfaces of suprasternal bones and their variations. Diagrams drawn from above, ossicles *in situ*, 1½ times natural size. Nos. 1, 3, 4, quadrilateral pyramids. In no. 4, both anterior and the left lateral surfaces are subdivided by secondary ridges. Nos. 2, 5, triangular pyramids. The medial surface is here compressed into a medial border. No. 6, irregular form exhibiting only medial and lateral surfaces. No. 1, blunt apices; nos. 2, 4, 5, rounded apices; no. 3, apex a transverse ridge; no. 6, apex an antero-posterior ridge.

the perpendicular (Fig. 1, nos. 1, 2, 3, 4, 5, 16). The less frequent flattened pyramids may bear resemblance to a biscuit (Fig. 1, nos. 7, 11, 15).

Position and relations. Ossicles of all types occupy a constant position on the posterior portion of the superior manubrial border. The manubrial facets adjoin and many times are confluent with the clavicular articular surfaces (Fig. 3). In other cases the suprasternal facet on the manubrium may be separated from the clavicular articular surface by a distinct groove (Fig. 3, no. 3). The surface of these facets on the manubrium, which are invariably present with well-developed ossicles, does not conform closely to that of the base of the suprasternal bones. The circumference of the facets is of more rounded outline than the base of the suprasternalia. The facets are with few exceptions broader in the lateral than in the antero-posterior direction. The larger facets generally present a central depression, the circumference appearing

as a rim (Fig. 3, no. 1). The surface of these facets is very variable, however. Sometimes it is concave only from side to side. In other instances it is convex antero-posteriorly. The facets are usually supported upon bony shoulders or pedestals which extend medially from the clavicular notches and to varying degree fill the jugular notch. In Fig. 1, no. 15, is seen a well-developed suprasternal bone upon a manubrium with markedly convex upper border. Here the manubrial facet is convex in all directions.

To clarify the further relationships of the ossicles dissections of two roentgenographed sterna bearing paired suprasternal bones were made (Nos. 2710 and 2705). These dissections revealed quite definitely the adaptation of the external form of the suprasternalia to their ligamentous investment and the interarticular disc of the sternoclavicular joint.

No. 2710 presented well-developed suprasternal bones of subequal size. The left ossicle was separate. It was joined to the sternum by a thin layer of fibrocartilage, the union thus being a synchondrosis. The base of the right ossicle was fused to the manubrium. Both suprasternal bones were of the triangular pyramidal type illustrated by Fig. 2, no. 2, and had well-defined surfaces. The anterior and posterior surfaces were each covered by strong ligamentous bands which joined the ossicles to the sternum. These might be termed the anterior and posterior suprasternal ligaments. They conform to the arrangement described by Luschka. Medially these ligaments became thin and blended with weaker ligamentous fibres which linked the rounded medial borders of the two bones to each other. Laterally the suprasternal ligaments blended respectively with the anterior and posterior sternoclavicular ligaments. To the entire lateral surface of each ossicle the interarticular disc of the sternoclavicular joint was firmly attached. The interclavicular ligament proper was easily separated from the fibres joining the bones to each other and passed above the suprasternal ossicles on each side, appearing to have no functional relation to them.

In the other specimen dissected (No. 2705) both ossicles had the triangular pyramidal form and were of subequal size. The disposition of the ligaments was the same as in the previous specimen. Anterior and posterior surfaces were covered by the corresponding suprasternal ligaments, and the broad medial borders were joined by thin strands of weaker fibres. Again the whole lateral surface of each ossicle constituted an impression for the attachment of the fibrocartilaginous meniscus.

The base of the left suprasternal bone articulated with the manubrium by a diarthrodial joint. The articular cartilage was limited to the contiguous surfaces and the synovial cavity had no communications. The right osselet though similar in size and shape to its mate was incompletely ossified. The roentgenogram revealed a pyramidal centre of ossification somewhat greater than half the size of the enclosing cartilage. As the individual in this case was 45 years of age it is believed that we are dealing with mature rather than incomplete development. The hyaline cartilage was united to the manubrium by synchondrosis.

Our findings on the relations of the suprasternal bones generally confirm and in some aspects expand and clarify the descriptions of earlier writers. The existence of definite surfaces and form previously mentioned and detailed by Luschka, in the accurate description of Anthony, but quite obvious in the plates of Breschet, von Eggeling and Dixon, has been shown to be constant, and recognizable even in the smaller and more rounded ossicles. Our dissections have shown that the anterior surface is regularly in relation with the thickening of the investing capsule called the anterior suprasternal ligament; that the posterior surface is constantly covered with a similar capsular specialization, the posterior suprasternal ligament; that the medial surface, whether it be broad and extensive or reduced to a mere rounded border, is joined to the corresponding surface of the companion ossicle by weaker ligamentous fibres which may be called the inter-suprasternal ligament; and that the lateral surface of the ossicles is contiguous with the interarticular disc of the sterno-clavicular joint. The interclavicular ligament was distinct as such and not a proper ligament of the suprasternalia.

These ligamentous arrangements agree essentially with those described with various emphasis by Luschka, Carwardine, Anthony, Lickley, Stein and Dixon. Of earlier writers Dixon alone specifically stated that the suprasternal bones were not connected with the fibrocartilaginous disc. Other authors reported definite connexion between the meniscus and the osselets. On each of the four sides in our two cases the disc was fused with the entire lateral surface of the suprasternal bones. When the disc was torn away, fragments of fibrocartilage remained adherent to the ossicles. In Anthony's case the menisci articulated with the suprasternal ossicles by diarthrodial joints. Dixon's finding is inexplicable in the light of other evidence, and it is accepted here that the meniscus articulates with the lateral surface of the ossicles by diarthrosis or synchondrosis and that the attachment is co-extensive with the lateral surface.

Integrity. Suprasternal bones which are incorporated in the manubrium exhibit a range of variation similar to that of the separate ossicles. Often recognition is difficult. Identification is most unmistakable when the fused ossicle is the subequal mate of a separate one (Fig. 1, no. 11). Fused ossicles of large size paired or single are readily perceived (Fig. 1, nos. 28, 30). In the more complete degrees of incorporation indentification of the suprasternal elements is difficult (Fig. 1, nos. 25–27). The line of junction between suprasternal bone and manubrium may be distinct (No. 825) or indistinguishable (No. 1032). Rounded episternal tubercles or ridges are likely to be confused with the shoulders adjacent to the clavicular facets discussed below. Occasionally extension of clavicular surface with arthritic deposit may mask a fused episternal element (Fig. 1, no. 29).

Examination of the superior manubrial aspects of mooted specimens will disclose true suprasternal tubercles in the characteristic position of the separate ossicles on the posterior portion of the margin (Fig. 3, nos. 25–30). It is freely admitted that in a few cases positive determination cannot be made.

It might be suggested that the minute ossicles of Fig. 3, nos. 9 and 23 are not mature suprasternal bones but centres of ossification of suprasternal cartilages not detectable on the roentgenogram. The specimens of no. 9 are from an individual of 55 years, that of no. 23 from one of 65 years. Despite an incomplete knowledge of the time schedule of development of the suprasternalia, there is no evidence that ossification of even these rudimentary structures would not be completed before the age of 30, for before this age all

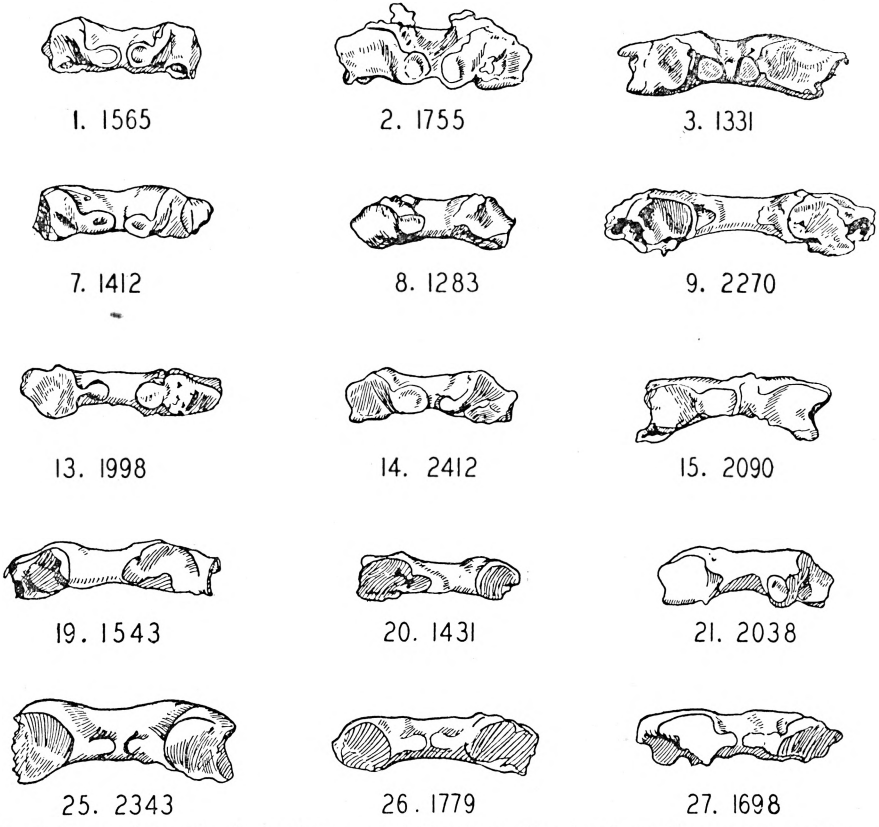


Fig. 3. Vertical aspects of superior manubrial borders. Showing facets for separate ossicles and fused ossicles themselves in constant position on posterior portion of superior border adjoining or adjacent to clavicular facets. Specimens same as in fig. 1.

manifestations of the phenomenon of growth of which the appearance of centres of ossification is but one have disappeared. Moreover, if the nodules were ossific centres in larger cartilages articulating with the manubrium, articular facets would be expected to be present on the manubrium. Examination of the upper manubrial borders of the specimens (Fig. 2 and Fig. 3, nos. 9 and 23), shows that such facets are absent. In addition, the great difference in size of the two ossicles of no. 9 would demand a special explanation if interpreted

as merely differential in developmental progress on the two sides, whereas unequal development of paired rudimentary structures is to be expected. The small ossicles cited, therefore, are regarded as having completed development in their respective individuals.

Structure. The roentgenograms show suprasternal bones to be of the same structure as the sternum. They consist of cancellous tissue invested with a very thin layer of compacta.

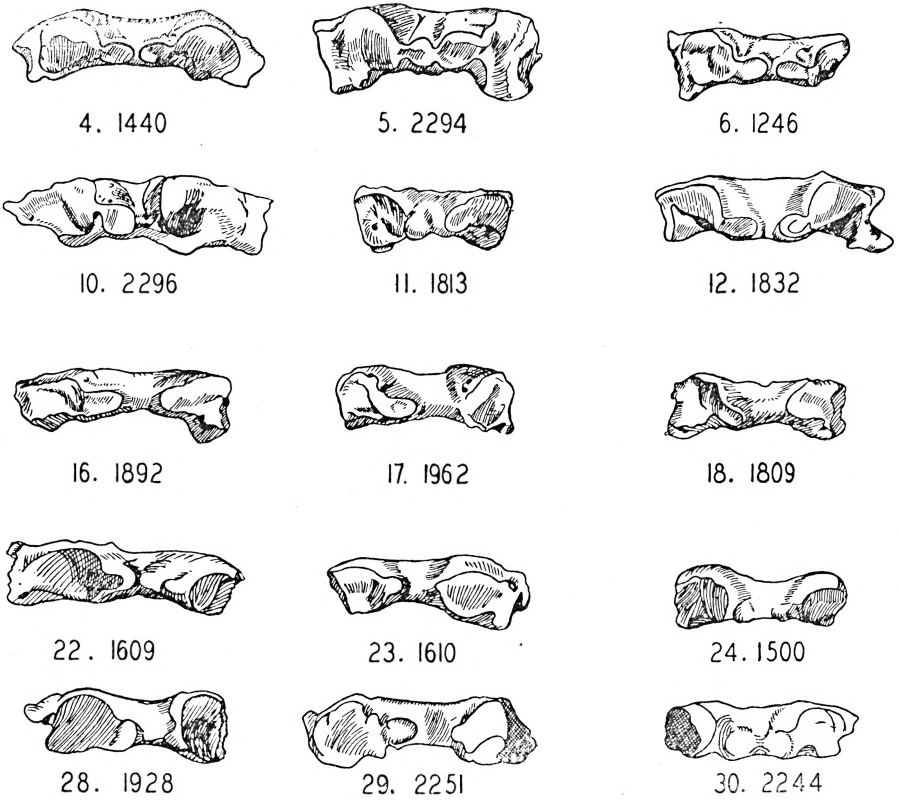


Fig. 3 (*continued*).

Value of the roentgenogram. In consideration of the incidence of the suprasternalia as shown in the tables, only the results of Series I, which consisted of sterna with roentgenograms taken before maceration will be used as final figures. The absence of suprasternal articular facets in the presence of definite suprasternal bones on the manubria of Fig. 3, nos. 9 and 23, as already mentioned, indicates that the dry sterna may yield no evidence of suprasternal bones which existed. It will be noticed also that both the absolute and relative incidence of separate suprasternal bones is greater in the first roentgenographed series than in the larger second series. Accordingly estimates of occurrence

must be based on sterna roentgenographed prior to maceration and not on dry manubria alone, as minute ossicles may be lost from the latter without trace.

Incidence

Classification. The morphological region involved in this study is the superior border of the manubrium between the clavicular notches. This border may be convex, straight, or concave in contour, or it may bear suprasternal ossicles or tubercles. The concave margin is of most frequent occurrence. It is the *incisura jugularis* of the text-books. In a large group of sterna, however, the jugular notch is encroached upon by rounded bony shoulders or buttresses of varying size which extend medially from the clavicular articular surfaces. Sterna of this type have been considered a modification of the concave type and designated "intermediate". In addition there are a few sterna of irregular type such as those of Fig. 4, nos. 16–18.

Both Von Eggeling and Paterson cited the anatomical features of the sterna here termed "intermediate". Von Eggeling called the bony shoulders "tubera jugulare" and found, as we did, that they might be either confluent with the clavicular notch or separated from the latter by a furrow. Von Eggeling was not definite on the significance of these tubera, but he did not appear to think them rudimentary suprasternal bones. Paterson mentioned "projections which formed ridges separated by grooves or facets from the clavicular facets", and, "distinct articular projections separate from or continuous with the clavicular articular surfaces". The articular projections he thought were sometimes for ossicles lost in maceration, but others and the ridges were "associated with variations in the mode of articulation of the clavicle or attachments of the sternoclavicular ligaments".

In dissections of the ligaments of five sterna of the intermediate type as shown by the roentgenograms we found that the bony shoulder or ridge in each case was the site of fixation of the meniscus. The attachment of the interarticular disc to the lateral side of suprasternal tubercles has been described by Luschka and Pansch and figured by the latter. This has also been shown in our dissection of No. 2710. Accordingly, a suprasternal ossicle, using the bony shoulder as a pedestal, merely separates the meniscus from a site of normal attachment.

Fig. 4. A. Variations of manubrial contour and width between clavicular facets. Left column, wide; middle column, medium; right column, narrow. Upper row, markedly convex; second row, slightly convex; middle row, straight; fourth row, slightly concave; bottom row, markedly concave. B. Irregular and intermediate upper manubrial contours. Nos. 16–18, oblique margins; nos. 19–23, encroachment of bony shoulders greater than one-half potential span of jugular notch; nos. 25–28, encroachment less than half span of jugular notch. Nos. 23, 26, 28, 29, line of attachment of clavicular ligaments visible outside of facet and running to medial limit of bony shoulder; nos. 19, 20, 22, 25, 30, bony shoulder and clavicular facet covered by single smooth continuous surface indicating extension of clavicular articular surface. No. 24, unilateral development of bony shoulder.

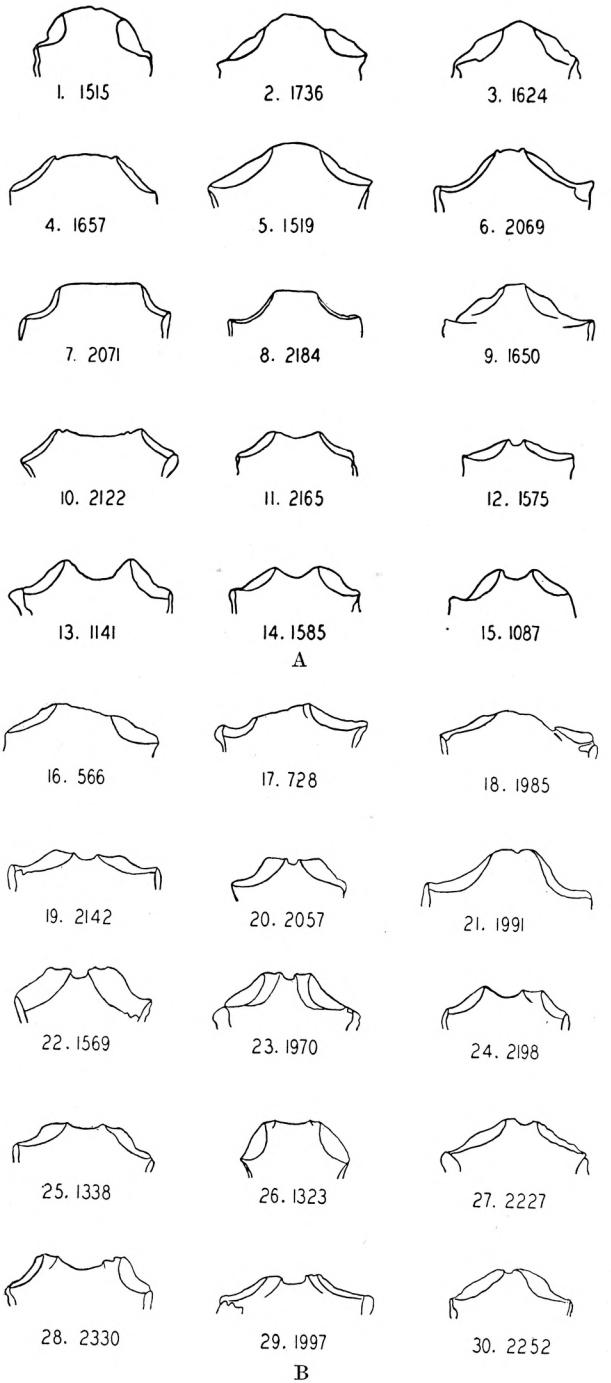

1. 1515
2. 1736
3. 1624
4. 1657
5. 1519
6. 2069
7. 2071
8. 2184
9. 1650
10. 2122
11. 2165
12. 1575
13. 1141
14. 1585
A
15. 1087
16. 566
17. 728
18. 1985
19. 2142
20. 2057
21. 1991
22. 1569
23. 1970
24. 2198
25. 1338
26. 1323
27. 2227
28. 2330
29. 1997
B
30. 2252

Fig. 4.

At this time No. 1283 becomes of special interest (Fig. 1, no. 8). It shows on the left a suprasternal ossicle supported on a bony shoulder or pedestal while on the right there is no shoulder, the ossicle articulating directly with the lateral side of the jugular notch. Nevertheless, on both sides the line of attachment of the sternoclavicular ligaments is perceptible. On the right this line runs up to a faint ridge on the jugular notch, at about the same distance from the adjacent clavicular notch as the breadth of the shoulder on the opposite side. On the left the line blends with the articular edge of the shoulder. Now had the ossicles in this case not been detected by the roentgenogram and preserved, the manubrium itself would have been classed as a unilateral "intermediate", for although the presence of a suprasternal bone on the left side would have been suspected, the articular surface was not sufficiently differentiated to warrant definite assumption, while on the right there was even less suggestion of the presence of a suprasternal bone.

It would thus appear that the attachment of the interarticular disc is marked in the jugular incisura by an impression elevated medially into a faint ridge (Fig. 3, no. 10), and that frequently this area may become raised into a shoulder or transverse ridge which also serves for attachment of the interarticular disc. When the suprasternal bones occur, they intervene between the attachment of the disc and the impressions or shoulders. The shoulders then serve as pedestals for the articulation of the suprasternal ossicles, the discs becoming attached to the lateral surfaces of the latter as has been shown. This relationship might permit suprasternal bones to be described as medial inclusions in the ligaments of the sternoclavicular joint, a slight modification of the concept of Carwardine, who regarded them as occasional inclusions in regularly occurring suprasternal ligaments.

In the present study all suprasternal elements not separate ossicles are included under the designation of suprasternal tubercle. The range of variation of the suprasternal tubercles has already been discussed.

In addition to being classified according to the character of the upper manubrial contour, the sterna were also arranged according to the degree to which the character was expressed. For all types the distance between the clavicular notches was noted as being wide, medium or narrow; convexity and concavity was either slight or marked; and in the intermediate group the encroachment of the bony shoulders was either greater or less than half the span of the potential jugular notch. This classification was purely an arbitrary one, made because it was natural and convenient and might hold the clue to some facts of functional significance.

The tables present the numerical and percentile incidence of the five principal types of upper manubrial border, namely, concave, intermediate, straight, convex, and with suprasternalia. The proper interpretation of these involves certain morphological and functional considerations.

Significance of manubrial types. The fact that evolutionary trend has been toward reduction of the number and size of shoulder-girdle elements at the

cranial end of the presternum would indicate that of the two extreme types of manubrial contour, the markedly convex or the deeply concave, the former is the more primitive.

It is obvious that the convex manubrium has a larger precostal portion than the concave. The significance of this precostal projection is difficult to determine. It may be produced by the incorporation in the manubrium of well-developed suprasternal bones which had fused to each other. Of this the manubria from cadavera Nos. 1440, 825 and 1032 are clear evidence.

No. 1440 (Fig. 1, no. 4) shows separate ossicles in close apposition which, fused to manubrium and each other, would produce a convex border. In No. 825 this fusion has actually occurred, but the lines of demarcation are still discernible. This manubrium is itself small but has relatively large suprasternal bones, and, were fusion complete to the degree manifest in No. 1032, it would be described simply as "convex". In No. 1032, however, small ossicles are incorporated in a large manubrium, and though no lines of fusion are apparent the ossicles are recognizable as a rounded transversely elongated eminence in their characteristic position on the posterior portion of the superior border. Viewed from behind, this manubrium presents a convex outline.

From No. 2090 (Fig. 1, no. 15), on the other hand, we learn that separate suprasternal bones may themselves be supported on a markedly convex manubrial border, and in such instances can have no part in the formation of the latter.

Markowski's figures of foetal and young specimens and the roentgenograms of the young individuals in our own Series III show convex, straight, and concave manubrial margins preformed in cartilage with ossification proceeding from a single manubrial centre. Thus, though a convex manubrial border may be formed by fusion of suprasternal bones, it may also arise independently of the ossicles.

From the comparative standpoint Paterson states that among the Mammals it is much commoner for the presternum to project in front of the first rib than not. He adds that the process may be median or bilobed; that when present it gives attachment to the clavicles; and that it is not characteristically present in sterna of the human type. The convex border may therefore be considered a manifestation of a frequent mammalian tendency for the presternum to project forward. It is conceivable that the human convex manubrium or the projecting manubrium of other Mammals may represent incorporated vestige of the omosternum of the Amphibia, though there is no evidence beyond topographical analogy to support this view.

Functionally the convex or projecting border would appear to provide a stronger basis for the sternoclavicular joint than the concave, with greater protection particularly against inward thrusts. There is slight indirect evidence for this in the higher percentages of intermediate sterna in the Negro as compared with the white. If it be true that the Negro has progressed further in the direction of simplifying structure at the upper end of the sternum, the

shoulders of the intermediate type can be interpreted as a secondary functional reaction to strengthen a weakened joint.

Dissections and statistics on the form of the manubrium from larger series of anthropoids than are at present available should throw more light on the amount of functional adaptation existing in the sternoclavicular joint, inasmuch as the amount of brachiation engaged in by each of these animals is adequately known.

The hypothesis which will be used as a basis for the analysis of our tables of incidence will be, therefore, that the human sternum with convex manubrial border and well-developed separate ossicles retains the greatest number and quantity of primitive shoulder-girdle elements and must be considered the primitive type, while the markedly concave sternum represents the greatest reduction in primitive elements and is hence the most advanced. Interpolated in descending order from advanced to primitive are intermediate, straight, and convex types, it being recognized that the intermediate may be interpreted both as a regressive straight type or a concave in which the notch is secondarily rebuilt.

The dangers of such an hypothesis in the absence of direct evidence is fully realized. Yet our indirect evidence is in a positive direction, and the opposite assumption, that the concave is primitive and the convex advanced, fails of support unless one assume the clavicles to be sliding down the sternum. To dismiss the whole matter as mere normal variation would seem to be dodging the problem.

Frequency of types of ossicles. The individuals from whom the suprasternal bones of this study were obtained are identified in Table II. It is immediately apparent that neither age, origin, cause of death nor associated sternal anomaly suggest that suprasternal bones have any particular constitutional affinity.

The frequency of paired, single, separate and fused ossicles appears in Table III. It will be noticed that the number and percentage of separate ossicles is much greater in Series I than Series II, while the reverse is true of tubercles. The apparent discrepancy is readily explained, first, by the fact already mentioned that the roentgenograms of Series I made possible detection of more ossicles than could be done in Series II, and second, because Series II contained a much larger proportion of male whites. The frequency in whites is greater than in Negroes, as will shortly be seen.

The disparity disappears when the percentages of suprasternal tubercles in the two groups are compared (Table III). These show no significant differences between the two series except in the female whites, who present a higher percentage of tubercles in Series I. The fact that these female white series were very small, numbering 79 and 83 individuals respectively, is to be taken into account.

As in the other tables of the incidence of suprasternal elements, the frequency shown by Series I is held most reliable. Because of the small numbers involved only the male series will be used. In the male whites of Series I,

Table II. *Cadavera with suprasternal ossicles or tubercles*

Sex and race	Cadaver No.	Age	Birthplace	Cause of death	Supra-sternalia*	Additional sternal anomaly or defect
				Series I. With X-rays		
Male, white	1246	39	United States	Cerebral haemorrhage	2 S	Manub., body united
	1331	27	United States	Carbon monoxide poisoning	2 S	None
	1412	31	Unknown	Carcinoma of stomach	2 S	None
	1431	42	United States	Alcoholic poisoning	2 S	None
	1440	79	Germany	Cerebral haemorrhage	2 S	None
	1543	75	United States	Cerebral haemorrhage	2 S	None
	1565	35	Unknown	Acute alcoholism	2 S	Large perforation
	1597	57	Unknown	Empyema of gall bladder	2 S	Sep. sternebra; perforat.
	2270	55	Unknown	Carcinoma of oesophagus	2 S	None
	2294	64	Unknown	Cerebral haemorrhage	2 S	Oblique man.-st. joint
	2299	50	Unknown	Myocarditis	2 S	None
	2457	44	Unknown	Pulmonary carcinoma	2 S	None
	2549	60	Pennsylvania	Arteriosclerosis	2 S	None
	2705	45	Unknown	Lobar pneumonia	2 S	None
	1609	61	Ireland	Auto accident	1 S	None
	1610	65	Italy	Auto accident	1 S	None
	1809	45	Unknown	Suicide	1 S	None
	1892	46	Greece	Pulmonary tuberculosis	1 S	Perforation
	2164	54	Unknown	Auto accident	1 S	None
	2187	37	Russia	Pulmonary tuberculosis	1 S	None
	2296	50	Unknown	Alcoholism	1 S	None
	2710	56	Unknown	Cardiac failure	1 S	None
	1813	66	Unknown	Gastritis	1 S, 1 T	None
	1998	64	Germany	Chronic nephritis	1 S, 1 T	Oblique man.-st. joint
	1500	70	United States	Chronic myocarditis	2 T	None
	1698	76	New York	Pyelocystitis	2 T	None
	2272	48	Unknown	Peritonitis	2 T	None
	2343	50	Unknown	Tuberculous meningitis	2 T	Half perfor. fr. ven. side
	1928	68	Serbia	Chronic myocarditis	1 T	None
	2251	61	Pennsylvania	Bronchial pneumonia	1 T	None
	2345	35	Unknown	Diabetes	1 T	Man. united to body
Female, white	1755	73	Austria	Cerebral haemorrhage	2 S	None
	1369	25	Ohio	Pulmonary tuberculosis	1 S	None
	1779	78	Germany	Bronchial pneumonia	2 T	None
	1938	79	Germany	Diabetes	2 T	Perf.; artic. 6 ribs
	2244	44	Hungary	Paresis	2 T	None (healed frac. corp.)
	1762	61	United States	Manic depressive psychosis	1 T	Very narrow, art. 6 ribs
Male, Negro	1283	23	Georgia	Pulmonary tuberculosis	2 S	None
	1962	42	Unknown	Dropsy	1 S	None
	2038	30	Unknown	Alcoholic poisoning	1 S	None
	2090	42	Alabama	Pulmonary tuberculosis	1 S	Sep. sternebra
	1832	37	Alabama	Coronary thrombosis	1 S, 1 T	Man. united to body
	2412	36	Ohio	Lobar pneumonia	1 S, 1 T	None
	1394	54	Tennessee	Rupture aortic aneurysm	1 T	None
	1507	22	Unknown	Pulmonary tuberculosis	1 T	None
	2005	53	Unknown	Skull fracture	1 T	None
	2016	45	Canada	Cardiac failure	1 T	None
Female, Negro	None					
				Series II. No X-rays		
Male, white	205	37	Austria	Myocarditis	2 S	None
	338	40	Unknown	Cerebral tumour	2 S	Body in two pieces
	395	55	Unknown	Lobar pneumonia	2 S	Perforation
	688	24	Unknown	Tuberculosis	2 S	None

* S, separate ossicle; T, tubercle.

Table II (*continued*)

Sex and race	Cadaver No.	Age	Birthplace	Cause of death	Supra-sternalia*	Additional sternal anomaly or defect
Male, white	255	48	Germany	Gangrene of foot	1 S	None
	746	45	Unknown	Skull fracture	1 S	None
	65	30	Unknown	Gunshot wound	1 S, 1 T	None
	424	26	Russia	Sarcoma	1 S, 1 T	Sl. obliquity man.-corp. joint
	429	40	Germany	Peritonitis	1 S, 1 T	None
	94	28	Unknown	Skull fracture	2 T	None
	104	35	Unknown	Lobar pneumonia	2 T	None
	115	88	Unknown	Nephritis	2 T	Manub. united to body
	383	35	Unknown	Suicide	2 T	None
	689	45	Unknown	Influenza	2 T	Manub. united to body
	701	41	Austria	Tuberculosis	2 T	None
	1032	73	Austria	Paresis	2 T	None
	1038	48	Bohemia	Pulmonary tuberculosis	2 T	None
	1045	49	Bohemia	Lues	2 T	None
	1164	49	Unknown	Pulmonary tuberculosis	2 T	Manub. united to body
	1230	58	Unknown	Skull fracture	2 T	None
	371	35	Unknown	Suicide	1 T	None
	489	64	Unknown	Tuberculosis	1 T	None
	550	39	Unknown	Tuberculosis	1 T	None
	997	40	Russia	Chronic myocarditis	1 T	None
	1013	60	New York	Mitral and aortic stenos.	1 T	None
	1179	35	United States	Alcoholic poisoning	1 T	None
Female, white	774	38	Unknown	Influenza	2 S	None
	631	31	Unknown	Myocarditis	2 T	None
	1066	51	Unknown	Arteriosclerosis	2 T	None
Male, Negro	25	35	Unknown	Unknown	1 S	None
	736	40	Unknown	Myocarditis	2 T	None
	825	21	Virginia	Pneumonia	2 T	None
	1201	29	Alabama	Pulmonary tuberculosis	2 T	Perforation
	778	28	Ohio	Tuberculosis	1 T	None
Female, Negro	868	60	Unknown	Myocarditis	2 S	None

* S, separate ossicle; T, tubercle.

46·5 per cent. of 31 cases of ossicles were paired and separate; 25·8 per cent. single and separate; 6·4 per cent. had one member of a pair separate and the other fused; 12·9 per cent. paired and fused; and 9·7 per cent. single and fused. The ossicles in the 10 male Negroes were paired and separate in 10 per cent.; single and separate in 30 per cent.; 1 separate, 1 fused in 20 per cent.; no fused pairs; but single fused ossicles in 40 per cent. Combining the stocks, out of 47 cases of ossicles in 1010 individuals, 34 per cent. were paired, separate; 25·5 per cent. single, separate; 8·5 per cent. paired, 1 separate, 1 fused; 14·8 per cent. paired, fused; 17 per cent. single, fused.

It may, therefore, be said that about two-thirds of the suprasternal ossicles which occur are separate and one-third fused; that paired ossicles are slightly more frequent than single in the separate group, but are of approximately equal frequency among fused ossicles. Although we are dealing with three times as many cases of ossicles in whites as in Negroes, the greater percentage of paired separate and single separate ossicles in the white indicates that this rudimentary structure attains fuller expression in the latter group, though

Table III. *Incidence of ossa and tubercula suprasternalia*

Type of ossicle	White						Negro						Total					
	Male		Female		Total		Male		Female		Total		Male		Female		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Paired separate:																		
I	14	46·5	1	16·7	15	40·5	1	10·0	—	—	1	10·0	15	36·6	1	16·7	16	34·0
II	4	15·4	1	33·3	5	17·2	—	—	1	100·0	1	16·7	4	12·9	2	50·0	6	17·1
I and II	18	31·6	2	22·2	20	30·3	1	6·7	1	100·0	2	12·5	19	26·8	3	30·0	22	26·8
Single separate:																		
I	8	25·8	1	16·7	9	24·3	3	30·0	—	—	3	30·0	11	26·8	1	16·6	12	25·5
II	2	7·7	—	—	2	6·9	1	20·0	—	—	1	16·6	3	9·6	—	—	3	8·5
I and II	10	17·5	1	11·1	11	16·7	4	26·7	—	—	4	25·0	14	19·4	1	10·0	15	18·3
Separate and fused:																		
I	2	6·4	—	—	2	5·4	2	20·0	—	—	2	20·0	4	9·7	—	—	4	8·5
II	3	11·5	—	—	3	10·3	—	—	—	—	—	—	3	9·6	—	—	3	8·5
I and II	5	8·8	—	—	5	7·6	2	13·3	—	—	2	12·5	7	9·7	—	—	7	8·5
Paired fused:																		
I	4	12·9	3	50·0	7	18·9	—	—	—	—	—	—	4	9·7	3	50·0	7	14·8
II	11	42·3	2	66·7	13	44·8	3	60·0	—	—	3	50·0	14	45·1	2	50·0	16	45·7
I and II	15	26·3	5	55·5	20	30·3	3	20·0	—	—	3	18·7	18	25·0	5	50·0	23	28·0
Single fused:																		
I	3	9·7	1	16·7	4	10·8	4	40·0	—	—	4	40·0	7	17·1	1	16·7	8	17·0
II	6	23·1	—	—	6	20·7	1	20·0	—	—	1	16·7	7	22·6	—	—	7	20·0
I and II	9	15·8	1	11·1	10	15·1	5	33·3	—	—	5	31·2	14	19·4	1	10·0	15	18·3
Total:																		
I	31	100·0	6	100·0	37	100·0	10	100·0	—	—	10	100·0	41	100·0	6	100·0	47	100·0
II	26	100·0	3	100·0	29	100·0	5	100·0	1	100·0	6	100·0	31	100·0	4	100·0	35	100·0
I and II	57	100·0	9	100·0	66	100·0	15	100·0	1	100·0	16	100·0	72	100·0	10	100·0	82	100·0
Percentages of tubercula suprasternalia (fused, paired and single)																		
I		1·5		5·0		2·0		1·2		0·0		0·9						1·5
II		2·4		2·4		2·4		1·8		0·0		1·1						2·0

this, of course, cannot be said of the form and development of individual ossicles.

Frequency of ossicles. The incidence of suprasternal ossicles and tubercles in our several groups is shown in Table IV. These results are compared with those of other investigators in Table V.

Again using the figures of Series I, it is seen that ossa or tubercula suprasternalia occurred in 6·8 per cent. of 544 adult whites and 2·2 per cent. of 466 adult Negroes. Incidence was highest in 79 white females, 7·6 per cent., lowest in 132 Negro females, 0·0 per cent. (Note that one pair of separate ossicles was found in a Negro female in Series II.) For the males the percentages were: 465 whites, 6·7; 334 Negroes, 3·0. Thus the suprasternal elements appear three times more frequently in whites than in Negroes. They are more than twice as frequent in white males than in Negro males, and nearly eight times more frequent in white females than in Negro females.

A difference in racial incidence so marked cannot fail to be striking when the small size of the female samples is considered. It is more arresting in the face of the hybridization which has certainly affected the Negro sample, though, as has been mentioned, hybridization has not been manifest in the physical characters of the laboratory sample to the same extent as in the American Negro as a whole.

Frequency of manubrial types. Returning to our hypothesis that the convex manubrium with well-developed suprasternal bones is the fullest expression in Man of the primitive elements of the shoulder girdle and the markedly concave the most removed from the primitive condition, it is significant to find, in addition to an incidence of suprasternal bones three times greater in whites than in Negroes, that the convex and straight manubrial borders also occur in greater percentage in whites than in Negroes, while the concave form is 7·5 per cent. more frequent in Negroes, both concave and intermediate types being grouped together as concave. For manubrial type both Series I and II were used, a total of 2139 individuals, there being no objection to this procedure here.

The incidence of the suprasternalia and the manubrial types thus seem to indicate a racial difference in development away from the primitive type of presternal end, the Negro having progressed further in this direction than the white.

Anthropoids. Table X shows the incidence of the several manubrial types in the anthropoid series of 61 gorillas, 38 chimpanzees and 8 orangs. No suprasternal ossicles or tubercles were found. The numbers of each animal are, of course, too small to permit any definite suggestion as to their occurrence in these Primates. It is of interest to note that 74 per cent. of the gorillas, 74 per cent. of the chimpanzees, and 62·5 per cent. of the orangs had concave borders, and that no gorillas or chimpanzees and but one orang had convex borders. This would imply further progress than Man has made away from the primitive type of sternum, an entirely plausible possibility, because in

Table IV. *Types of manubria according to sex and race*

Series	White						Negro						Total					
	Male		Female		Total		Male		Female		Total		Male		Female		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Concave																		
I	241	51·9	41	51·2	282	51·8	160	47·9	62	47·0	222	47·6	401	50·2	103	48·8	504	49·9
II	401	57·8	41	49·4	442	56·9	151	56·7	44	61·9	195	57·8	552	57·5	85	55·2	637	57·2
I and II	642	55·4	82	50·6	724	54·8	311	51·8	106	52·2	417	51·9	953	54·2	188	51·5	1141	53·7
Intermediate																		
I	109	23·4	15	18·9	124	22·7	120	35·9	49	37·1	169	36·3	229	28·6	64	30·3	293	29·0
II	147	21·2	18	21·7	165	21·3	74	27·8	16	22·5	90	26·7	221	23·0	34	22·1	255	22·9
I and II	256	22·1	33	20·4	289	21·9	194	32·3	65	32·0	259	32·2	450	25·6	98	26·8	548	25·8
Straight																		
I	52	11·2	16	20·2	68	12·5	40	11·9	17	12·9	57	12·2	92	11·6	33	15·6	125	12·4
II	85	12·3	20	24·1	105	13·5	26	9·8	7	9·8	33	9·8	111	11·6	27	17·5	138	12·4
I and II	137	11·8	36	22·2	173	13·1	66	11·0	24	11·8	90	11·2	203	11·6	60	16·4	263	12·4
Convex																		
I	32	6·9	1	1·2	33	6·1	4	1·2	4	3·0	8	1·7	36	4·5	5	2·4	41	4·1
II	34	4·9	1	1·2	35	4·5	10	3·7	3	4·2	13	3·8	44	4·6	4	2·6	48	4·3
I and II	66	5·7	2	1·2	68	5·1	14	2·3	7	3·5	21	2·6	80	4·5	9	2·5	89	4·2
Ossa or tubercula suprasternalia																		
I	31	6·7	6	7·6	37	6·8	10	3·0	0	0·0	10	2·2	41	5·1	6	2·8	47	4·6
II	26	3·7	3	1·8	29	3·7	5	1·9	1	1·4	6	1·8	31	3·2	4	2·6	35	3·1
I and II	57	4·9	9	5·5	66	5·0	15	2·5	1	0·5	16	2·0	62	4·1	10	2·7	82	3·9
Total																		
I	465	85·5	79	14·5	544	53·9	334	71·7	132	28·3	466	46·1	799	79·1	211	20·9	1010	47·6
II	693	89·3	83	10·7	776	69·7	226	78·4	71	21·6	337	30·3	959	86·2	154	13·8	1113	52·4
I and II	1158	87·7	162	12·3	1320	62·2	600	74·7	203	25·3	803	37·8	1758	82·8	365	17·2	2123	100·0

Table V. *Incidence of ossa suprasternalia and manubrial types according to various investigators*

Series	No. sterna in series	Spec. with separate ossicles		Spec. with tubercles only		Spec. with ossa or tubercles		Superior manubrial margin					
								Convex		Straight		Concave*	
		No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Strauch	200	5	2·5	6	3·0	11	5·5	—	—	—	—	—	—
Paterson	563	1	0·2	44	7·8	45	7·9	35	6·2	16	2·8	467	82·9
Bogusat	120	3	2·5	—	—	3	2·5	—	—	—	—	—	—
Eggeling	226	9	4·0	21	9·3	30	13·2	53		23·4		144	64·6
Barchielli	162	0	0·0	3	1·8	3	1·8	7	4·3	43	26·5	109	67·2
W.R.U., I	1010	33	3·3	14	1·3	47	4·6	41	4·1	125	12·4	797	78·9
W.R.U., II	1113	12	1·1	23	2·0	35	3·1	48	4·3	138	12·4	892	80·1
W.R.U., I and II	2123	45	2·2	37	1·7	82	3·9	89	4·2	203	12·4	1689	79·5

* Includes both concave and intermediate types.

many characteristics of the higher Primates one or more of the great apes has attained more advanced development than that found in Man.

The higher Primates have relatively short and broad sterna as contrasted with the lower. Schultz(77) has shown that siamang, orang and gorilla have each progressed further in this direction than has Man. Nor is it found that the genus which shows the most advanced development in one of the higher Primate characters exhibits similar advancement in all. Thus although the chimpanzee manifests to a marked degree the tendency to fusion of the segments of the corpus sterni most fully realized in Man, yet in relative breadth the sternum of the chimpanzee is not much greater than that of the lower Primates. Similarly, though the orang has attained a tremendously short and broad sternum, the segments of the corpus tend to remain ununited, except the most caudal.

Our findings in the region of the hafting of the shoulder girdle are thus in full accord with Primate tendencies in development as revealed by evidence now available. There is no reason to expect in other regions or relationships of the human sternum correlated advanced or primitive stages. Unfortunately the literature does not yield at present adequate information on the morphology of the human sternum. Those series which have been studied are on the whole too small to furnish satisfactory knowledge of the variations and their incidence, racial and otherwise, of this highly variable bone.

Width of superior manubrial border. In surveying the aspects of the subject which should be explored in an investigation of suprasternal bones, it appeared that the proximity of the clavicular facets as measured by the distance separating them might have possible functional significance. Accordingly an attempt was made to obtain information on this phase by classifying each upper manubrial border as being relatively wide, medium or narrow. The results appear in Tables VI and VII, illustrated by fig. 4, which show wide, medium and narrow varieties of the several types of manubrial contour. These appraisals of width are empirical commonsense estimates, undoubtedly neither so desirable nor as accurate as indices derived from actual measurement of the superior borders and the manubria themselves, but still possessing a practical value.

Examination of Table VII, which shows the number and percentages of the widths irrespective of the type of contour, reveals no racial and but slight sexual difference. Of the combined series 34·5 per cent. were classed as wide, 52·7 per cent. as medium and 12·7 per cent. as narrow in distance between their clavicular articular surfaces. The males show approximately 12 per cent. more borders with widely spaced articular surfaces than the females, while the white females have 7 per cent. more borders with narrow-spaced surfaces than the white males. The proportion of narrow borders between the sexes is nearly the same in the Negro series.

From this it may be said that the distance along the superior manubrial border between the clavicular articular surfaces has a greater tendency to be

Table VI. *Distribution of sterna according to contour of superior manubrial border, sex and race*

Contour of manubrium	Distance between clavicular articular surfaces: Wide, Slight		Wide, Marked		Medium, Slight		Medium, Marked		Narrow, Slight		Narrow, Marked		Total	
Convex:													Series I	Series II
White: Male	12	4	6	3	7	12	5	8	2	4	—	3	32	34
Female	—	—	—	—	1	—	—	1	—	—	—	—	1	1
Negro: Male	1	2	—	—	1	2	2	4	—	—	—	2	4	10
Female	2	—	1	—	1	—	—	2	—	1	—	—	4	3
Total	15	6	7	3	10	14	7	15	2	5	—	5	41	48
Straight:	Series I		Series II		Series I		Series II		Series I		Series II			
White: Male	25		37		21		42		6		6		52	85
Female	7		7		8		11		1		2		16	20
Negro: Male	17		7		17		17		6		2		40	26
Female	8		—		8		6		1		1		17	7
Total	57		51		54		76		14		11		125	138
Concave*:	Deep		Shallow		Deep		Shallow		Deep		Shallow			
White: Male	31	21	75	69	54	118	52	124	9	33	20	36	241	401
Female	—	1	8	6	11	6	12	15	1	2	9	11	41	41
Negro: Male	20	8	47	18	33	44	27	50	16	18	17	13	160	151
Female	1	—	20	1	13	12	16	21	6	3	6	7	62	44
Total	52	30	150	94	111	180	107	210	32	56	52	67	504	637
Intermediate:	En $<\frac{1}{2}$ N		En $>\frac{1}{2}$ N		En $<\frac{1}{2}$ N		En $>\frac{1}{2}$ N		En $<\frac{1}{2}$ N		En $>\frac{1}{2}$ N			
White: Male	58	34	23	11	10	65	17	32	—	2	1	3	109	147
Female	4	2	4	1	4	9	2	4	1	2	—	—	15	18
Negro: Male	48	17	21	3	21	35	29	17	1	2	—	—	120	74
Female	10	2	2	—	18	9	16	4	3	—	—	1	49	16
Total	120	55	50	15	53	118	64	57	5	6	1	4	293	255
												Total	963	1078

* May show small tubercles for ligamentous attachment but no bony shoulders.

† Bony shoulders or tubera encroach upon jugular notch.

N.B. The first column under each heading refers to Series I and the second column to Series II.

wide relative to the breadth of the manubrium in males than in females. The meaning of this tendency is not now obvious. The anthropoid data are too limited to permit of functional comparisons based on the brachiating habits of the apes and the generalized use of the upper limb in Man. The data as further subdivided in Table VI shed no additional light on this phase. Hence, there appears no association between the width of the superior manubrial margin and suprasternal bones such as existed between the latter and the contour of the manubrial margin.

Age incidence of ossa suprasternalia and manubrial types. The 82 suprasternal ossicles and tubercles encountered in this study all occurred in adults. In the roentgenograms of our 65 young subjects no suprasternal elements, ossified or cartilaginous, were found.

Table VII. *Incidence of wide, medium and narrow upper manubrial borders*

	Wide		Medium		Narrow		Total	
Sex and race	No.	%	No.	%	No.	%	No.	%
White: Male	409	37·1	567	51·5	125	11·4	1101	100·0
Female	40	26·1	84	54·9	29	18·9	153	100·0
Negro: Male	209	35·7	299	51·1	77	13·2	585	100·0
Female	47	23·3	126	62·4	29	14·3	202	100·0
Total	705	34·5	1076	52·7	260	12·7	2041	100·0

The age curves of the subjects having suprasternal bones are not dissimilar from those of the series themselves as plotted from the data of Tables VIII and IX respectively, so that the median or percentage age incidence are of no value. The youngest subject in our series having suprasternal bones was No. 825, a male Negro of 21 years. The specimens were fused but well developed as previously described (p. 265). There were in all ten cases of suprasternalis in the third decade.

The developmental history of suprasternal bones in the light of present evidence may be briefly stated as follows. Suprasternal bones originate in two lateral condensations of mesoderm from the median anlage of the sternum, independent of the sternal bands and ribs. The anlagen become cartilaginous. Suprasternal cartilages have been found in foetuses of 6 months (Paterson). These may persist into adult life (Breschet). Ossification has been observed earliest at $12\frac{1}{2}$ years (von Eggeling). It is probable that ossification generally occurs toward the end of the second decade as part of the last wave of maturation processes which includes epiphysial union and the ossification of vertebral, costal and clavicular epiphyses. The ossification of the cartilage is usually complete but may be partial.

The age incidence of the several types of manubrial contour was plotted, but no type exhibited a particular age incidence such as Graves has found for the vertebral border of the scapula.

Associated anomaly. Since Carwardine, Lickley and Leboucq thought suprasternal bones to be associated with or a manifestation of defective osseous

Table VIII. *Age incidence of ossa suprasternalia*

	White									Negro									Total		
	Male			Female			Total			Male			Female			Total					
Age	I	II	I and II	I	II	I and II	I	II	I and II	I	II	I and II	I	II	I and II	I	II	I and II	I	II	I and II
20–29	1	3	4	1	—	1	2	3	5	2	3	5	—	—	—	2	3	5	4	6	10
30–39	5	6	11	—	2	2	5	8	13	3	1	4	—	—	—	3	1	4	8	9	17
40–49	6	11	17	1	—	1	7	11	18	3	1	4	—	—	—	3	1	4	10	12	22
50–59	7	2	9	—	1	1	7	3	10	2	—	2	—	—	—	2	—	2	9	3	12
60–69	8	2	10	1	—	1	9	2	11	—	—	—	—	1	1	—	1	1	9	3	12
70–79	4	1	5	3	—	3	7	1	8	—	—	—	—	—	—	—	—	—	7	1	8
80–89	—	1	1	—	—	—	—	1	1	—	—	—	—	—	—	—	—	—	—	1	1
Total	31	26	57	6	3	9	37	29	66	10	5	15	—	1	1	10	6	16	47	35	82

Table IX. *Distribution of sterna according to age by decade, sex, race, and contour of superior manubrial border*

	White														Negro										Total W and N				
	Male					Female					Total					Male					Female					Total					
Age	Cv.	St.	Cc.	In.	Total	Cv.	St.	Cc.	In.	Total	Cv.	St.	Cc.	In.	Total	Cv.	St.	Cc.	In.	Total	Cv.	St.	Cc.	In.	Total	Cv.	St.	Cc.	In.	Total	Cv.	St.	Cc.	In.	Total
Series I. Sterna with roentgenograms																													
0–19	—	—	1	—	1	—	—	1	1	2	—	—	2	1	3	—	—	1	—	1	—	—	1	1	2	—	—	2	1	3	—	—	4	2	6
0–29	1	1	6	5	13	—	1	1	—	2	1	2	7	5	15	—	7	25	18	50	2	1	18	16	37	2	8	43	34	87	3	10	50	39	102
0–39	1	7	17	5	30	—	—	5	2	7	1	7	22	7	37	—	4	42	29	75	—	7	18	9	34	—	11	60	38	109	1	18	82	45	146
0–49	9	11	61	25	106	—	4	11	4	19	9	15	72	29	125	2	15	38	28	83	—	3	10	11	24	2	18	48	39	107	11	33	120	68	232
0–59	10	16	71	34	131	—	1	10	2	13	10	17	81	36	144	1	7	28	28	64	2	2	6	5	15	3	9	34	33	79	13	26	115	69	223
0–69	10	14	50	24	98	1	4	5	1	11	11	18	55	25	109	1	4	17	11	33	—	3	5	2	10	1	7	22	13	43	12	25	77	38	152
0–79	1	2	27	12	42	—	3	4	3	10	1	5	31	15	52	1	2	6	3	12	—	2	4	2	8	1	4	10	5	20	2	9	41	20	72
0–89	—	1	8	4	13	—	3	4	1	8	—	4	12	5	21	—	1	2	2	5	—	—	1	1	2	—	1	3	3	7	—	5	15	8	28
0–99	—	—	—	—	—	—	—	—	1	1	—	—	—	1	1	—	—	1	—	1	—	—	—	—	—	—	—	1	—	1	—	—	1	1	2
Total	32	52	241	109	434	1	16	41	15	73	33	68	282	124	507	5	40	160	119	324	4	18	63	47	132	9	58	223	166	456	42	126	505	290	963
Series II. Bones only																													
0–19	—	—	3	—	3	—	—	2	—	2	—	—	5	—	5	—	3	6	2	11	—	1	2	1	4	—	4	8	3	15	—	4	13	3	20
0–29	4	4	25	15	48	—	—	5	5	10	4	4	30	20	58	3	5	56	14	78	2	2	8	4	16	5	7	64	18	94	9	11	94	38	152
0–39	4	15	81	27	127	—	10	10	1	21	4	25	91	28	148	1	8	37	25	71	—	1	17	3	21	1	9	54	28	92	5	34	145	56	240
0–49	5	19	112	40	176	—	2	11	3	16	5	21	123	43	192	5	4	33	16	58	—	1	6	3	10	5	5	39	19	68	10	26	162	62	260
0–59	12	23	80	31	146	—	1	8	4	13	12	24	88	35	159	1	5	14	10	30	—	1	4	2	7	1	6	18	12	37	13	30	106	47	196
0–69	6	13	60	20	99	1	3	3	3	10	7	16	63	23	109	—	1	4	4	9	—	1	6	1	8	—	2	10	5	17	7	18	73	28	126
0–79	3	9	29	13	54	—	3	1	2	6	3	12	30	15	60	—	—	1	2	3	1	—	1	—	2	1	—	2	2	5	4	12	32	17	65
0–89	—	2	11	—	13	—	1	1	—	2	—	3	12	—	15	—	—	—	1	1	—	—	—	2	2	—	—	—	3	3	—	3	12	3	18
0–99	—	—	—	1	1	—	—	—	—	—	—	—	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	1
Total	34	85	401	147	667	1	20	41	18	80	35	105	442	165	747	10	26	151	74	261	3	7	44	16	70	13	33	195	89	331	48	138	637	254	1078
and II	66	137	642	256	1101	2	36	82	33	153	68	173	724	289	1254	15	66	311	193	585	7	25	107	63	202	22	91	418	255	787	90	264	1142	544	2041

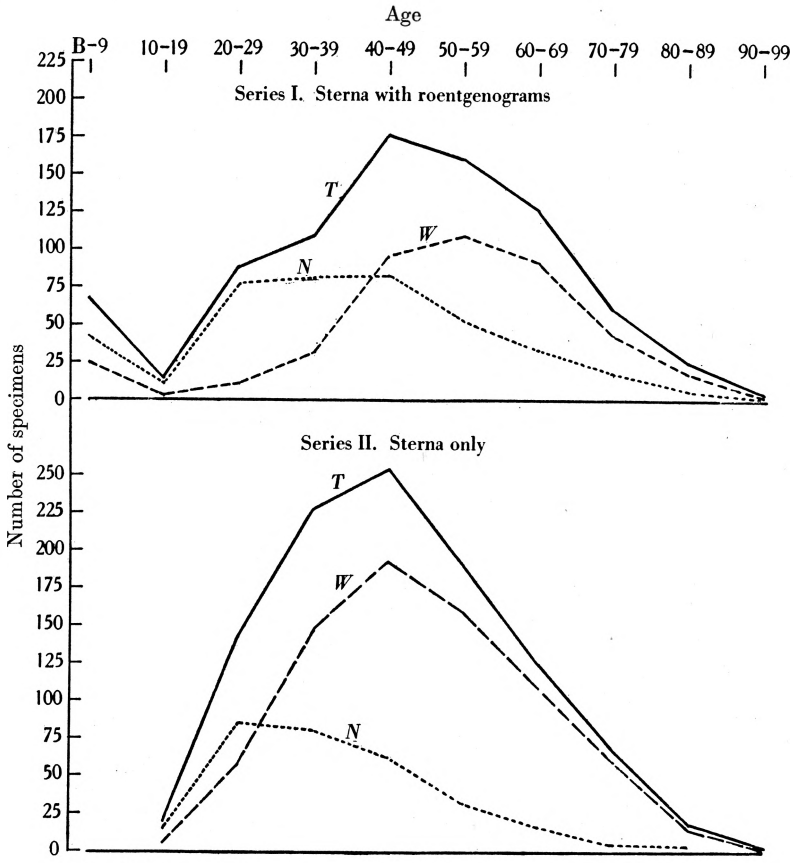
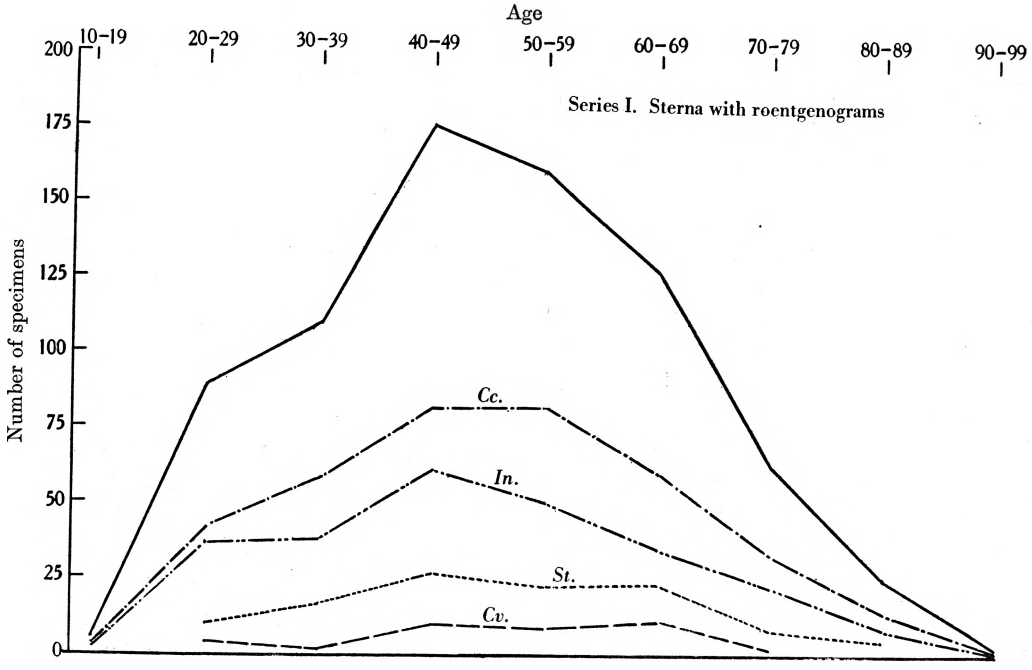


Fig. 5. Distribution of sterna according to age by decade and race.



development in the sternum or elsewhere, and Malaguzzi-Valeri held that the mere fact that two individually rare anomalies, the suprasternalia and cervical rib, had been several times reported together was itself significant, special attention was given to such association in our specimens.

Table II shows that of the 82 sterna bearing suprasternal elements 69 or 84·1 per cent. were in all other respects normal, including 6 specimens in which manubrium and body were united, this feature not being eligible as

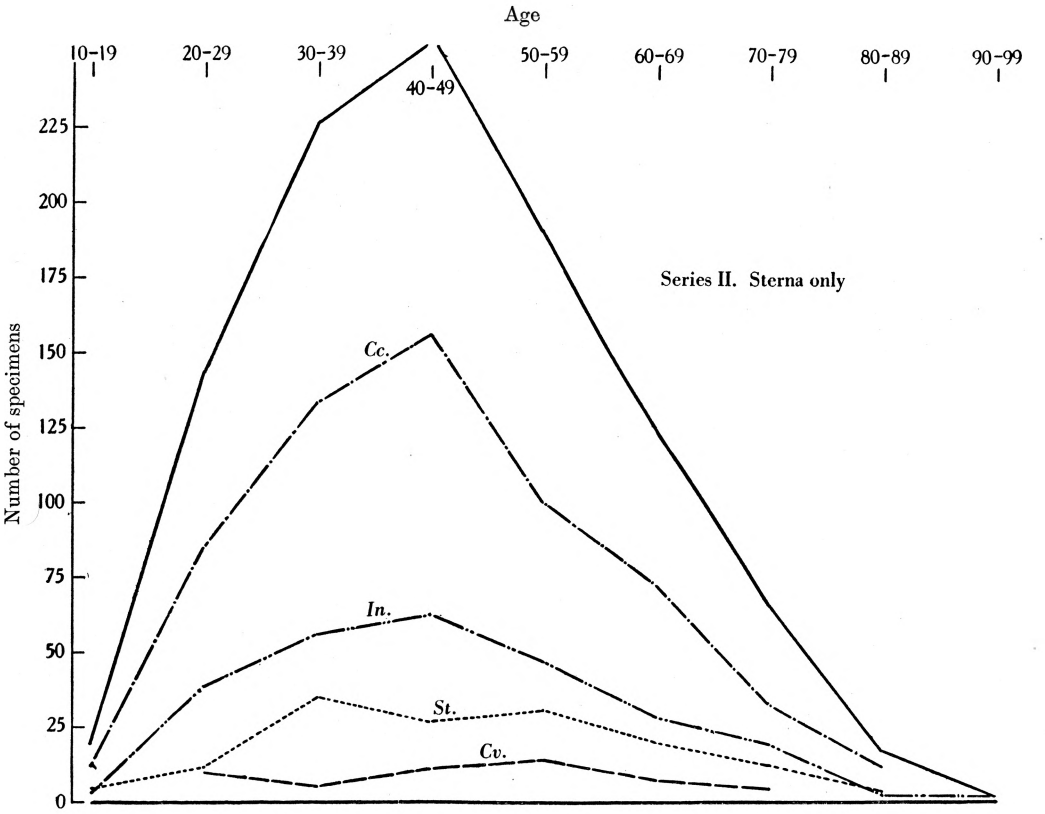


Fig. 7. Distribution of sterna according to age by decade and contour of superior manubrial border.

an anomaly. Six specimens of 7·3 per cent. had perforations of the corpus; in three, 3·6 per cent., the manubrio-corporeal joint was oblique from side to side instead of horizontal; in three sterna the body presented separate sternebrae; and one sternum, 1·2 per cent., had an unusually short and narrow corpus which articulated with only six ribs. It is quite evident then, that suprasternal bones have no particular association with anomaly or defect in the sternum.

Table X. *Incidence of manubrial types in anthropoids*

	Gorillas			Chimpanzees			Orangs		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
Concave	30	15	45	7	21	28	1	4	5
Intermediate	8	5	13	2	5	7	—	—	—
Straight	2	1	3	—	3	3	1	1	2
Convex	—	—	—	—	—	—	1	—	1
Total	40	21	61	9	29	38	3	5	8

The cervical vertebrae of 79 of the 82 cases of suprasternal bones were examined for cervical rib. In no case was this structure found, so that particular association with this anomaly must also be denied. (Of the three cases not examined, two were in maceration and one was missing.)

V. SUMMARY

The variation and incidence of suprasternal bones and the form of the superior manubrial border were investigated on 2204 human and 107 anthropoid sterna in the Hamann Museum of Western Reserve University, a larger and better documented collection of material than has hitherto been available.

Roentgenograms of 1010 of the human sterna taken before maceration and with the clavicular ligaments still attached made possible the detection of minute ossicles otherwise lost. Comparison of manubria with their roentgenograms demonstrated that the dry manubrium may show no evidence of a suprasternal bone which was present. The incidence of separate ossicles was relatively higher in our roentgenographed series than in that composed of dry bones alone. Estimates of incidence based on macerated material are, therefore, unreliable.

The facts about suprasternal bones as they now appear may be briefly stated as follows:

1. *Development.* Suprasternal bones originate in occasional lateral condensations of mesoderm from the median anlage of the sternum, which is associated with the shoulder girdle and is independent of the sternal bands and ribs. The anlagen become cartilaginous. The cartilaginous stage has been noted at six foetal months and may persist into adult life. Ossification has been observed as early as 12½ years. It probably generally occurs between the ages of 17 and 23. Ossification of the cartilage may be partial or complete.

2. *Homology.* Suprasternal bones appear to be rudiments of the epicoracoids of the primitive shoulder girdle, as evidenced by their constancy of attachment to the interarticular disc of the sternoclavicular joint, the constancy of their position on the sternum, and their homologous relationships with intermediate structures in the lower Vertebrates.

3. *Size.* Suprasternal bones range in size between that of a small shot and an average female lunate bone. An average is: length 10·4 mm., breadth 10·4 mm., height 7·3 mm.

4. *Form.* The shapes of suprasternal bones are variants of a quadrilateral pyramid having a base, four surfaces and an apex. The base articulates with the manubrium; the interarticular disc is attached to the lateral surface; the medial surface or border is joined by the inter-suprasternal ligament to its fellow or the sternum; the anterior and posterior surfaces are bound to the manubrium by the anterior and posterior suprasternal ligaments, respectively, specialized portions of the capsular ligament of the sternoclavicular joint. The apex is medially situated. Reduction in size and rounding of the margins tend to mask the characteristic form of the ossicles, but this may be discerned even in fused specimens. Most commonly the medial surface is contracted into a broad border producing a triangular pyramid.

5. *Structure.* Suprasternal bones are similar in structure to the sternum. They consist of cancellous tissue surrounded by a thin layer of compactum.

6. *Position.* Ossicles of all types occupy a constant position on the posterior manubrial border, adjoining and many times confluent with the clavicular articular surfaces but sometimes separated from the latter by a groove, which serves for ligamentous attachment.

7. *Variation.* Suprasternal bones occur in pairs and singly. They may be separate, forming a diarthrodial joint with the manubrium complete with articular cartilage and synovial membrane; they may be united to the manubrium by synchondrosis; or as small nodules they may be ensconced within the suprasternal ligaments and have no contact with the manubrium. The ossicles exhibit various degrees of fusion with the manubrium and with each other, almost complete incorporation in the former being sometimes detectable. When fusion occurs can only be surmised but is probably early. Paired suprasternal bones may be of subequal size and symmetrical form and position on the manubrium, or of unequal size and asymmetrical arrangement. One element may be separate and the other fused.

8. *Incidence.* The roentgenograms showed separate or fused suprasternal bones in 6·8 per cent. of 544 adult whites and 2·2 per cent. of 466 adult Negroes. The incidence was highest in 79 white females, 7·6 per cent.; lowest in 132 Negro females, 0·0 per cent. (One case of ossicles in a female Negro was found in the second series.) For the males the percentages were: 465 whites, 6·7; 344 Negroes, 3·0. Thus the ossicles appear three times more frequently in whites than in Negroes. They are more than twice as frequent in white males as in Negro males, and nearly eight times more frequent in white females than in Negro females.

9. *Frequency of types of ossicles.* About two-thirds of the suprasternal ossicles which occur are separate and one-third fused. Paired ossicles are slightly more frequent than single in the separate group, but paired and single are of approximately equal frequency among fused ossicles. The separate ossicles occur about 30 per cent. more often in whites than in Negroes.

10. *Classification of manubrial types.* The superior manubrial border may be convex, straight or concave. A convex border may be produced by the

fusion of suprasternal bones, or it may support separate ossicles. A concave border may be encroached upon by bony shoulders which serve for the attachment of the meniscus and at the edges the sternoclavicular ligaments. Sterna with such shoulders are classed as intermediate.

11. *Significance of manubrial types.* The human sternum with convex manubrial border and well-developed separate ossicles retains the greatest number and quantity of primitive shoulder-girdle elements and must be considered the primitive type, while the markedly concave sternum represents the greatest reduction in primitive elements and is hence the most advanced. Interpolated in descending order from advanced to primitive are intermediate, straight and convex types, it being recognized that the intermediate may be interpreted both as a regressive straight type or a concave in which the jugular notch is secondarily rebuilt.

12. *Frequency of manubrial types.* Convex and straight manubrial borders occur in greater proportion in whites than in Negroes, while the concave form is 7·5 per cent. more frequent in Negroes, both concave and intermediate types being grouped together as concave. This fact, coupled with the greater incidence of ossicles of all types and the greater proportion of separate ossicles in the whites, seems to indicate that the Negro has progressed further than the white in simplification of the upper end of the presternum.

13. *Age incidence of ossa suprasternalia and manubrial types.* The 82 ossicles and tubercles encountered in this study all occurred in adults. The age curve of these individuals compared with that of the series as a whole revealed nothing significant. The age curves of the several types of manubrial contour revealed no particular age incidence for any type such as Graves found for the vertebral border of the scapula.

14. *Associated anomaly.* The suprasternal elements in this series revealed no particular association with any anomaly or defect in the sternum, and were in no case associated with a cervical rib.

15. *Width of superior manubrial border.* The distance along the superior manubrial border between the clavicular articular surfaces has a greater tendency to be wide relative to the breadth of the manubrium in males than in females.

16. *Anthropoids.* In the anthropoid series of 61 gorillas, 38 chimpanzees and 8 orangs no suprasternal ossicles or tubercles were found, but their superior manubrial border was classified in the same way as the human. No gorillas and chimpanzees and but one orang had convex manubrial borders, but 75 per cent. of these animals had concave borders. This suggests further progress than Man has made away from the primitive type of sternum.

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