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Anatomical Studies No. 65: Two Cases of Cervical Ribs in Bovines.*

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In domesticated mammals variations in rib number, additions as well as reductions, are by no means uncommon. However, according to authorities such as Ellenberger and Baum (1921) and Sisson (1927), the seat of the anomaly is usually the caudal extremity of the series. Frequently changes of a compensating nature are encountered in the adjoining lumbar region. As regards variations at the junction of the thoracic and the cervical regions, an extensive search of the literature has revealed but two recorded cases (Bradley, 1902; Corton, 1923), both of which relate to the equine species.

In the human being, in which, as a result of pressure on some of the components of the brachial plexus, the presence of cervical ribs is usually accompanied by clinical symptoms, a fair number of recorded cases are to be found (Gladstone and Wakeley, 1933). This leads one to suspect that in domesticated animals the rarity of the condition may be more apparent than real; it may be due to lack of attention to a detail which, from the purely veterinary viewpoint, appears to be of but slight importance. Be this as it may, there is ample justification for a rather detailed discussion of two cases of cervical ribs recently encountered in bovines.

Description of Material.

Case No. 1.

Subject.—Pure-bred Sussex bull, D.O.B. 4292, aged seven years and ten months.

History.—This animal had been used as a sire at the Armoedsvlakte Research Station. Although from his veterinary history sheet he is found to have suffered from several sporadic conditions, there is no record of lameness in the forelimbs, nor of atrophy of the musculature of the shoulder and forearm. On account of his age and his decreased procreative powers, this bull was slaughtered on 5.8.37.

Skeleton.—Over the entire skeleton there are present large exostoses. These seem to be the result of exuberant ossification mainly at points where cartilage persists until late in post-natal life, e.g. the intervertebral discs and the scapular cartilages.

* A communication left by the late Dr. Cloete in manuscript form and revised by C. Jackson and H. P. A. de Boom.

The formula for the vertebral column, namely $C_7T_{13}L_6S_5Cy$-, does not depart from the normal. Both the atlas and the axis are unaffected. In the third cervical vertebra a notch cuts in deeply between the dorsal and the ventral components of the transverse process, making for two almost separate processes (Fig. 1). In the fourth vertebra this separation is even more distinct and here the lateral (more caudal) part is rather thick and massive (Fig. 2). In the following segment (Fig. 3), the junction between the two parts, i.e. the lateral wall of the *foramen transversarium*, has become so attenuated as to resemble, instead of a sagittal plate, a thin rounded shaft. Here, too, the ventral part has become platelike and has assumed a ventro-lateral position, while the lateral (caudal) branch has shifted dorsally to lie on a level with the floor of the vertebral foramen. Its extremity is massive, rounded and rough. In the sixth vertebra (Fig. 4) the foramen transversarium is no longer complete; however, small pointed projections remain to indicate the position of its lateral wall. The extremity of the lateral branch of the transverse process appears to have undergone compression which has rendered it shorter and more massive, with a large, flat but rough free surface facing ventro-laterally. The posterior vertebral notches are deeply excavated.

At a glance the seventh vertebra (Fig. 5) might be mistaken for the first thoracic. The spinous process, which in the previous segment is already increasingly prominent, is now of excessive length. Here the transverse process hardly projects outwards and it is placed somewhat lower than usual; it is now nothing more than a massive elevation on the lateral aspect of the body of the vertebra. On its ventro-lateral free surface is carried an oval, concave articulatory facet, measuring 2·7 cm. along its greatest diameter. At their bases there is no distinct separation between the transverse and the anterior articulatory processes. The posterior vertebral notches are very deep and on the right side a caudally placed ossified strip converts the notch into a short canal. In addition to those on the transverse processes, the usual facet for the head of the first thoracic rib is also present.

The first thoracic (8th serial) vertebra exhibits only one small anomaly, namely, the articular surface for the tubercle of the rib is, dorso-ventrally, concave instead of convex. The transverse process of the 20th vertebra (last thoracic) bears no costal facets—quite a common variation in bovines.

Apart from the exostotic condition already mentioned the remainder of the vertebral column shows no abnormalities.

The ribs are fourteen in number; however, at their sternal ends the first two of either side are fused. As the last thirteen undoubtedly represent the normal thoracic series, the most cranial one must be a cervical rib.

Save for the greater length of its tubercle the first thoracic rib (Fig. 6) is of usual size and shape. Its vertebral extremity appears to have undergone rotation about the long axis of the rib, the plane through the head and tubercle having moved squarer to the median plane. The sternal end of this rib is wide and flat and to its anterior edge is fused the lower extremity of the cervical rib. The latter has straight borders and a slightly concave medial surface. In width and thickness it is similar to the first thoracic rib. In the absence of a head, the sole articulating surface is carried on the tubercle. The caudal border has a length of 9 cm. and the cranial, 20 cm. The ventral extremity is indicated by the clearly demarcated diagonal line of fusion with the first thoracic rib. On the anterior border, at the junction of the upper and middle thirds, there is a smooth transverse groove, probably the impression of a nerve or an artery. About 7 cm. nearer the sternal extremity there is a similar but more distinct impression. Opposite this the pattern of the bone is irregularly radiating. Apparently as the result of pressure at this point the normal process of bone construction has suffered disturbance. This cervical rib has no costal cartilage and makes no union with the sternum.

In keeping with the variation noted in the thirteenth thoracic vertebra, the last rib carries no facet for articulation with the transverse process of this segment.

No further skeletal anomalies are evident.

Case No. 2.

Subject.—A cow, D.O.B. 2292, aged 11 years and 2 months. This animal was a half-bred Sussex out of an indigenous or native cow.

History.—This was an experimental animal at Armoedsvlakte. Being in the "control" herd of the bonemeal feeding experiment, she received no phosphorus supplement. After having produced three calves she consistently failed to conceive and therefore she was slaughtered on 25.3.38.

Skeleton.—The few anomalies observed are confined to the vertebral column and the ribs.

The normal number of presacral vertebrae is present. Only the seventh and the twentieth segments exhibit any abnormalities. The former is modified in much the same way as, but to a lesser degree than, the corresponding vertebra in Case No. 1. It has a laterally compressed transverse process carrying a concave facet for the tubercle of the cervical rib. The twentieth vertebra is typical of the thoracic series and it has all the usual costal articulatory facets, even those on the transverse process. However, these surfaces are not smooth; they do not appear to have been worn against an opposing hard bony surface. The same applies to the caudal costal facets on the body of the twelfth thoracic vertebra.

On each side there are thirteen ribs. On each side the two cranial members of the series are fused and resemble in practically every respect the corresponding ribs in Case No. 1. As before, the first rib articulates with the seventh cervical vertebra and is, therefore, a cervical rib. The remaining ribs represent the normal first twelve thoracic ribs and the usual thirteenth thoracic is missing. The fact that on the corresponding vertebra some attempt at facet formation is evident leads one to believe that some very rudimentary, doubtlessly cartilaginous, rib must have been present. Its insignificance may be judged from the fact that it escaped detection at the very thorough and detailed examination to which each experimental carcase is subjected.

Discussion.

The various theories advanced in explanation of the occurrence of ribs attached to the seventh vertebral segment are briefly summarised by Gladstone and Wakeley (1933) *.

(1) *Excalation of a cervical segment.*

(2) *Fusion of two cervical segments.*

* The terms used are those of the authors cited.

In both instances the number of presacral vertebrae is reduced, and as this reduction has occurred in the cervical region the seventh segment of the series is actually the first thoracic and hence the rib in question is the normal first rib.

(3) *Forward movement of the ribs along the vertebral column.*—The total number of vertebrae remains unchanged, but individual segments are modified in adaptation to the changed position of the ribs. Thus in the bovine the seventh segment will resemble the thoracic type while the twentieth vertebra will exhibit lumbar characters. The increased number of segments in the latter region, as well as the presence of the normal number of presacral vertebrae should serve to differentiate this from the first two types. However, it is stated that the pelvis may also be involved in this forward movement, in which case the above criteria become invalid; the decision will then hinge upon the character of the seventh segment—whether it is a true thoracic or a modified cervical vertebra, and this may not be at all easy to decide.

(4) *Variation about a Mean,* or, in Bateson's (1894) classification, " homoeotic variation ". It is postulated that a transitional segment may assume the character typical of an adjoining region. According to the direction of the change these variations are referred to as forward or backward homoeosis. The occurrence of a cervical rib is said to be an example of the latter type—the cervical vertebra assuming the character of the more caudally placed thoracic region.

It is apparent that in the bovine a case of backward homoeosis affecting both the seventh and the twentieth vertebra will be indistinguishable from one of forward shifting of the ribs without involvement of the pelvis.

(5) *Atavistic Variation.*—Wiedersheim and Parker (1907) state that there has been a gradual phylogenetic reduction in rib-number, and that the occasional presence of supernumerary ribs is to be explained as " reversion ". Gladstone and Wakeley (1933) make the same point in maintaining that cervical or lumbar ribs are atavistic variations.

In many of the lower vertebrate forms, cervical ribs are normal features. In the crocodile they are present along the entire cervical region. Even in the domestic fowl and in the ostrich cervical ribs persist throughout adult life. By the possession of ribs the vertebrae have not lost their identity with the cervical region, nor do we regard them as having assumed thoracic characters.

Thomson (1926) states that as a *descriptive* term for summing up cases where organisms exhibit ancestral traits which their parents did not possess, the word " reversion " is useful, convenient, and, to his mind, legitimate. He does not agree with Professor Karl Pearson's suggested restriction of this term to instances where the ancestor is definite and the use of the term " atavism " for throwbacks to a remote and indefinite ancestor. Thomson regards the latter term as an unnecessary synonym. Let us for the moment agree to use the words " reversion " or " atavism " in their descriptive sense. Later in this discussion it will be necessary to be more critical as to the exact impression we wish the term to convey.

At this stage it is well to consider in the light of these theories the two cases described in this article.

Without hesitation the first two theories may be discarded; in neither case is there any reduction of the number of presacral vertebrae. The presence of fourteen ribs in the first case renders the theory of forward movement of the ribs inapplicable. In the second case this theory might still be entertained; however, the twentieth segment is typically thoracic, while the seventh shows but slight signs of modification. These facts, coupled with the evidence of an attempt, no matter how abortive, at formation of a thirteenth thoracic rib, lead one to conclude that the first rib in the series is definitely a supernumerary, cervical rib. Hence, in this instance too, the third theory may be dismissed.

In both cases the decision must be between the homoeotic and the atavistic theories. To satisfy the postulates of the former, "substantive variation" of the vertebra towards the present day thoracic type must be demonstrable. Failing this, the atavistic theory, in its wide interpretation, must succeed; the more so as it is known that true cervical ribs do occur in many of the lower vertebrates.

In Case No. 1 it has already been indicated that the transformation of the seventh segment may be regarded as the cumulative effect of increasingly evident variations, detectable as far forward as the third cervical vertebra. This is well demonstrated by graphic presentation of the dimensions * of these segments. In Fig. 7 overall width of some cervical and thoracic vertebrae is considered. As compared with the controls both the peak (at C_3) and the sudden drop (after C_6) have shifted one vertebra cranialwards. The chief gain in length of the spinous processes (Fig. 8) occurs sooner (nearer the cranial extremity) than in the controls—notice the steeper slopes from C_5 to C_7 and the more horizontal lines from the latter to the peak at T_3. All these variations are confined mainly to the cervical section of the vertebral column. Similar but less distinct differences are obtained with other dimensions. These graphs have been omitted.

These findings indicate conclusively that the modifications evident in the seventh vertebra are not to be interpreted as a spasmodic local variation of this segment towards the adjacent thoracic type; the factor responsible for this variation acted not only in the immediate vicinity of the thoraco-cervical junction, but also more remotely, affecting the entire cervical region with the exception of the first two highly specialized segments. Moreover, although the tendency of the modification is to close the gap between the usual last cervical and first thoracic vertebrae, this appearance may equally well be due to reversion to a more primitive cervical type which had much in common with the present thoracic picture. At all events, despite its modifications the segment in question departs less from the true last cervical character than from that of the first thoracic. Consequently it must be regarded as conforming, both in position and in appearance, to the cervical region. One has to conclude that the variation considered here does not fall within the scope of the homoeotic theory, thus leaving as the only feasible explanation that based upon reversion or atavism.

After this a decision on the second case is not difficult. Here, apart from the facet on its slightly modified transverse process, the seventh segment displays but one anomaly, namely a longer spinous process. In none of the other dimensions is any significant departure from the control figures to be detected. It is obvious that this segment departs from the usual character of the seventh vertebra to a very limited degree. Save that its articulatory surfaces have not been subjected to wear, the twentieth segment is true to type. In view of these facts one has no hesitation in again implicating the atavistic theory.

* These dimensions were measured according to the system in vogue in the Section of Zootechny of this Institute. The control figures are from bovines of similar age, sex and breeding, kept under identical environmental conditions. Actually many more controls were referred to, but for clarity only two are included in the figures presented in this article.

Through a process of elimination we have arrived at the conclusion that both the described anomalies are atavistic or reversionary variations. It is now imperative to define with accuracy what we wish these terms to convey. To return to Thomson (1926), " when we go beyond the use of the word as a descriptive term, and use it as implying that ancestral characters reappear because they are parts of inheritance, which have been lying latent for generations, and have suddenly been allowed by some liberating stimulus to express themselves in development, we pass from fact to interpretation, from description to theory, and great care is necessary ". In taking biologists to task for the too liberal use of the term atavism, Montagu (1938) points out that the exhibition by any organism of some characterstic peculiar to an ancestor does not necessarily imply that this is the result of a sudden rehabilitation of some latent item of inheritance.

We know that in their blastemal stage all the vertebral segments are alike and that the costal process is present along the entire series. Only during the stage of chondrification does differential development of this rib *Anlage* occur. While in the thoracic region it grows into a fully formed rib, in the cervical region it remains small, and fuses with the vertebra to form the *foramen transversarium*. The presence of a cervical rib must be the result of sudden stimulation of the sluggish costal process with consequent abnormal growth. It is clear that heredity has supplied the material from which this structure is produced; however, the nature of the stimulus remains to be considered.

In this connection Stockard's (1921) work on the causation of monsters is interesting. He has been able to produce numerous anomalous conditions merely through inducing sudden changes in the metabolic rate of the developing organism. He maintains that every part of the body has its own specific critical period during which it assumes dominance over the remaining, temporarily dormant parts. During this state the latter are pracically immune to metabolic disturbances, whereas the dominant part is highly susceptible to them. Decreased metabolism will slow down development and will prevent this part from becoming fully established during its preferent period—a setback from which it can never recover completely. On the other hand, a suddenly increased rate enables the already dominant region to make abnormally good use of its critical period, resulting in excessive development of this part, perhaps even to the detriment of others.

In the light of this theory the acquired sluggishness of the cervical costal process may be regarded as the result of severe restriction of the critical time allowed for its establishment. This in turn may have been brought about by severe telescoping of critical periods during the evolution of a more and more complex organism—the periods allowed for structures which are apparently unnecessary would be the first to suffer curtailment. The material is still there, it is still capable of full development, but it has been almost obliterated through the usurpment of most of its critical time by other parts.

It appears that this suppressed structure may be restored to full or partial development either by sudden acceleration of the metabolic rate during its critical period, thus enabling it to make extraordinarily advantageous use of its extremely limited time, or by sudden decreases of metabolism during the critical periods of those structures which have encroached upon its time, thus retarding these and minimising their suppressing influence. In either case the activation is bound up with metabolic changes. As Stockard and others have pointed out, these changes may all be related to the rate of passage of the fertilized ovum down the Fallopian tube, to the rate and manner of implantation, to the condition of the uterus and to the state of the mother. Thus the stimulating factor which activates the hereditary material is contained in the environment of the developing organism.

One may now ask why under these circumstances all the cervical costal processes do not develop into ribs. The answer is twofold: Firstly, the degree of suppression of the process is greatest in the most cranial, highly specialized segments; from here it becomes gradually less. Hence the caudalmost cervical segment has less leeway to make up and it follows that with equal stimulation at equally favourable moments this cervical segment will show the greatest degree of response; the preceding segments will exhibit a gradually diminishing degree of reaction. Secondly, as growth passes wave-like down the column, it follows that the peak instants of any two segments will never coincide, that of the more cranial element always being the earlier. A sudden change in the developmental rate cannot affect all the segments equally—the effect will always be graded over several adjacent vertebrae, being most pronounced in the one which happens to be caught at the summit of its development. By virtue of its position in the series, the last cervical is able to respond to stimulants coming too late to have any effect upon the more cranial segments. Again, it is hardly conceivable that the action of any activating agent would be spread over such an infinitely short period as to allow of its affecting the more cranial segments only.

Thus we see that in the matter of developing cervical ribs the most caudal segment of the series possesses an overwhelming advantage. Almost invariably it will be the seventh cervical vertebra which will carry the rib, while those segments immediately preceding it will at most exhibit anomalies indicating some increased development of the costal process. This is exactly what is seen in the two cases described in this article, more particularly the first.

Summary.

After giving a description of two instances of cervical ribs in bovines, these cases are considered in the light of various theories that have been advanced in explanation of such anomalies. It is concluded that both of them are covered by the atavistic or reversionary theory, which is here specifically defined as indicating that heredity has supplied the material from which, through stimulation probably emanating from the organism's environment, there develops a structure resembling that which was normally present in an evolutionary ancestor.

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Fig. 1.—Third cervical vertebra (Case No. 1). (Left ventro-lateral view.)

Fig. 2.—Fourth cervical vertebra (Case No. 1). (Left ventro-lateral view.)

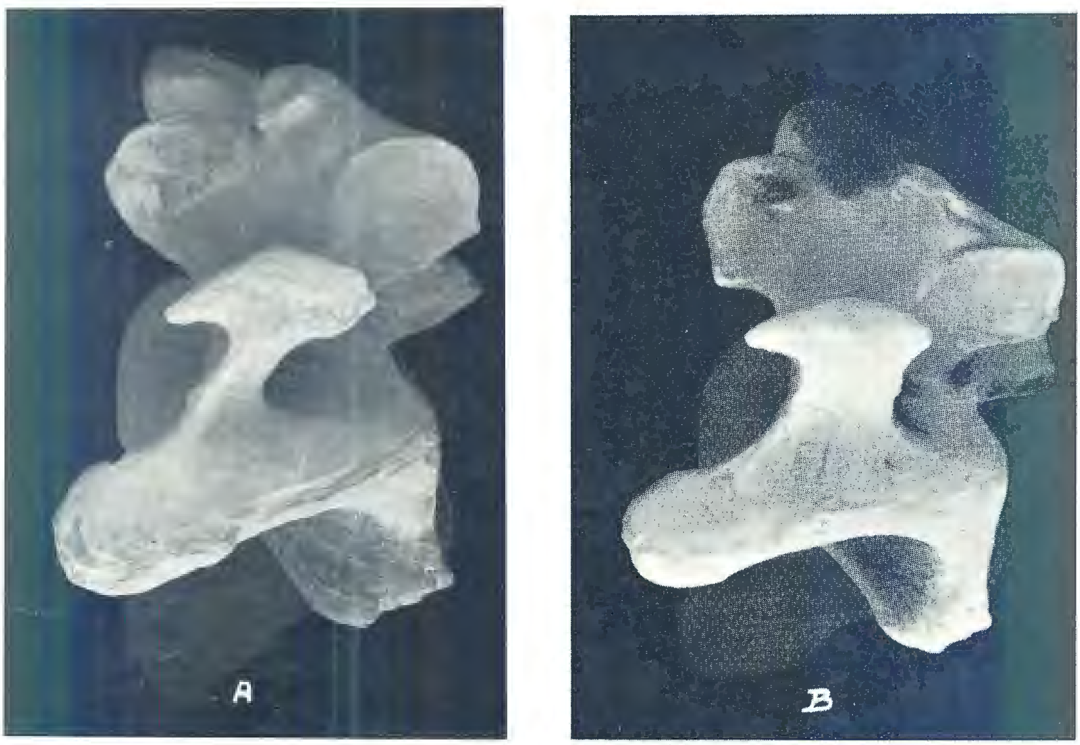

Fig. 3.—A: Fifth cervical vertebra (Case No. 1). B: Normal C_5 for comparison. (Both taken from left ventro-lateral angle.)

Fig. 4.—A: Sixth cervical vertebra (Case No. 1). B: Normal C_6 for comparison. (Both taken from left ventro-lateral angle.)

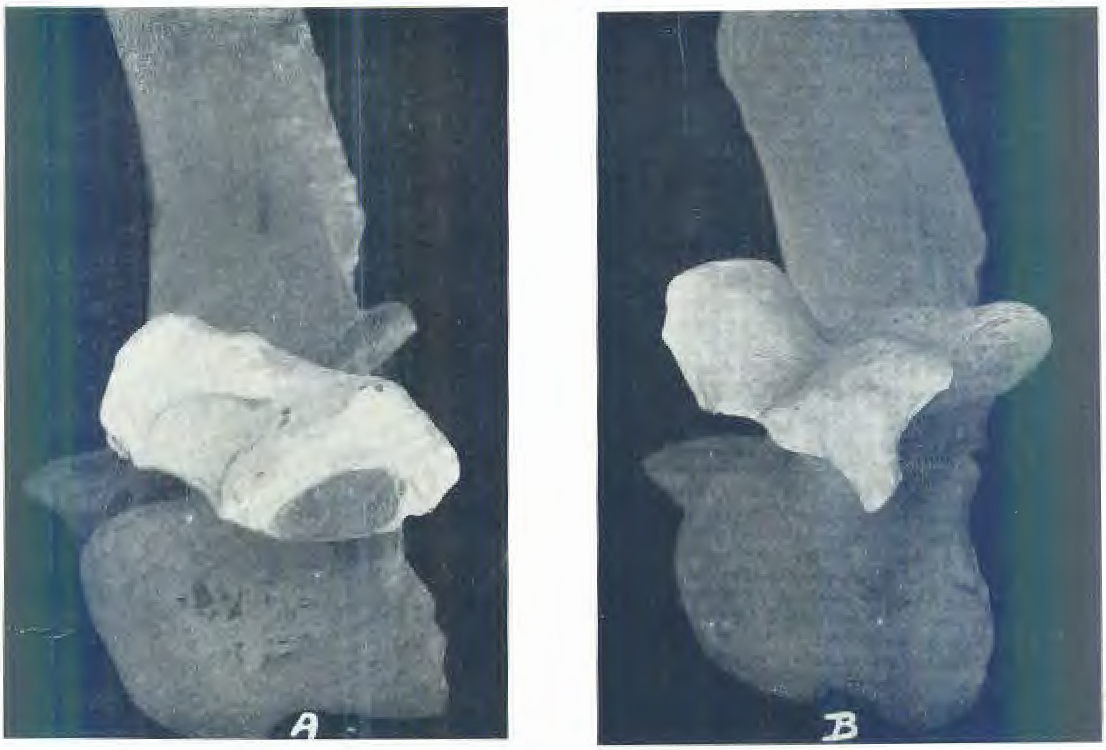

Fig. 5.—A: Seventh cervical vertebra (Case No. 1). B: Normal C_7 for comparison. (Left lateral views.)

Fig. 6.—Left: Cervical and first (thoracic) rib (Case No. 1). Right: A normal first rib for comparison.

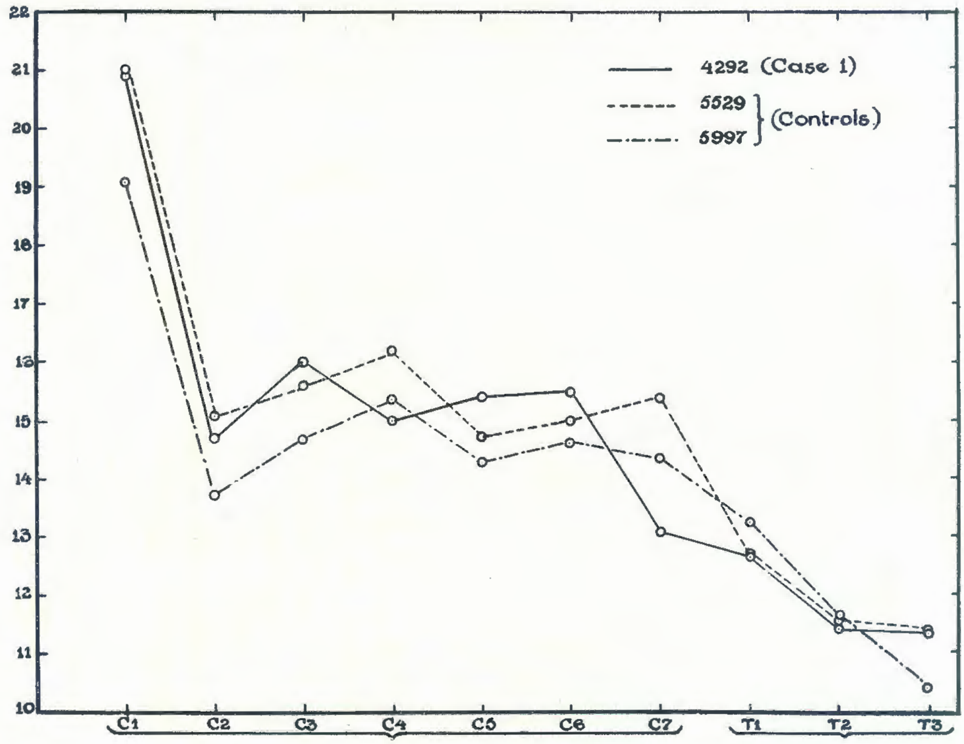

Fig. 7.—Width of cervical and thoracic vertebrae (cms.).

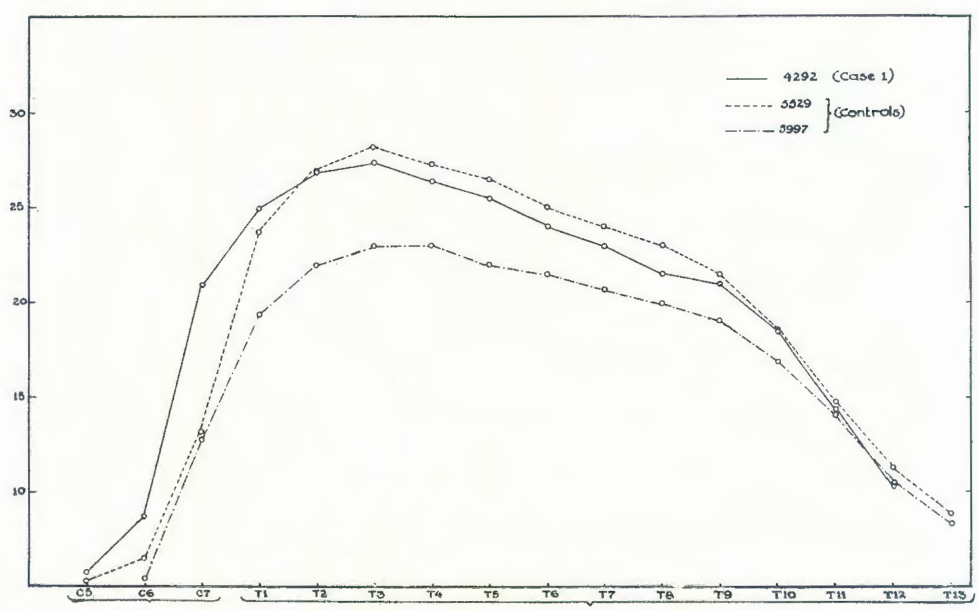

Fig. 8.—Length of spinous processes (cms.).