CERVICAL RIBS AND RUDIMENTARY FIRST THORACIC RIBS CONSIDERED FROM THE CLINICAL AND ETIOLOGICAL STANDPOINTS

By REGINALD J. GLADSTONE, M.D., F.R.C.S. and CECIL P. G. WAKELEY, F.R.C.S. (Eng.), F.R.S. (Edin.)
University of London, King's College

A large number of cases of 7th cervical and rudimentary 1st thoracic ribs have now been recorded, but there is much yet to be learned about these abnormalities. The relations of these abnormal ribs to the vertebral column and sternum, and to the principal nerve trunks, vessels and muscles have been minutely described by various authors, partly from the surgical, and partly from the morphological aspect. From the surgical standpoint, with regard to the relief of pressure symptoms by the removal of a part of the rib, or the division of the fibrous or muscular structures attached to it; and by anatomists with reference to the meaning of these variations considered from the morphological standpoint.

The true cause of these variations in the number, size and position of the ribs, and of their varying relations to the vertebral column and sternum, does not appear to have been discovered, although several well-known theories have been advanced in the attempt to find a solution of this difficult problem. Some of these theories are conflicting in nature, or inconsistent with ascertained facts; but as yet, nobody has either definitely confirmed or refuted certain of the particular points at issue. For instance: Do these variations indicate a general tendency towards decrease or increase in the number of ribs in the human race? or have they no phylogenetic significance? Are these variations germinal in origin? or are they due to some disturbance of the normal segmentation in early embryonic development? Are cervical ribs and additional vertebrae to be regarded as an exuberance of development, and rudimentary ribs or diminution of the number of ribs and total number of vertebrae, as defects of development? or is there a common cause for both types of variation? Is Ruges' theory of the formation of the right and left sternal bars by fusion of the ventral ends of the cartilaginous anterior thoracic ribs correct? or are the mesodermal bars which precede the development of the cartilaginous sternum evolved independently of the ribs in a mass of condensed mesodermal tissue, which arises medially between the rudiments of the shoulder girdle, and extends backwards in the form of two mesenchymal bars? This theory was propounded by Melville Paterson, and subsequently reaffirmed by other workers; for instance, Whitehead and Waddell, who hold that the bars arise *in situ* and join the median rudiment secondarily, and Hanson who believes that the sternum is an homologous structure throughout all groups of verte-

brate animals, that the anterior elements of the sternal apparatus arise in common with the shoulder girdle in intimate relation with the coracoids, and that the sternal bars, although they may be associated with the ribs secondarily, do not arise from these. This question we intend to deal with in a subsequent communication on the development of the sternum. It may be advisable, however, to state here that the evidence, both of ontogeny and of comparative anatomy, appears to support the latter view, the sternum primarily having been evolved in certain fishes and tailless Amphibia, as a support for the shoulder girdle, as a firm site of origin for the pectoral muscles and quite independently of the ribs. In *Rana* the ribs are short; they do not reach the sternum, and have no respiratory function; yet in the frog, the sternal apparatus is a well-developed structure consisting of an "episternal process," connected by fused epicoracoid cartilages with the sternum proper and the metasternum. It is, moreover, joined on each side by a well-developed clavicle and coracoid. The various conflicting theories which have been put forward by such authorities as Eisler, Rosenberg, Bateson or Weidersheim are well known. The last of these authors, it may be recalled, regarded the occurrence of cervical ribs in Man as an "atavism," and rudimentary 1st thoracic ribs as a "progressive variation," while others considered that the variations in the number of the costal elements and their relations to the vertebrae are simply "variations about a mean," which take place in the transitional regions of the vertebral column, and have no evolutionary importance.

It is not our purpose here to enter generally into the difficult question of meristic variations; we wish, however, to draw attention to a factor which appears to have an important bearing on the cases with which we are dealing. In a large proportion of the reported cases of cervical ribs and rudimentary 1st thoracic ribs, other anomalies have been present in the same subject. These are undoubtedly defects of development which have occurred at an early stage of embryonic life, and cannot thus be regarded as germinal variations having a phylogenetic significance. These defects of development are not limited to the skeletal system, but involve other systems such as the nervous and vascular. Some of these defects are primary in nature, and appear to be due to a disturbance of the normal process of segmentation; others are secondary and are produced as a direct result of the primary defect, e.g. complete absence, imperfect development, or atrophy of muscles owing to pressure on nerves; or are compensatory changes, e.g. the development of an adventitious joint in an unusual situation to compensate for absence of cleavage, or fusion of segments which normally articulate with each other by movable joints, figs. 1 and 2. They include such defects as congenital scoliosis of the vertebral column; synostosis and imperfect development of vertebrae; fusion of the atlas vertebra with the occipital bone; irregularity and asymmetry in the development of the base of the skull; anencephalus, spina bifida and syringomyelia; imperfect development of the clavicles; suppression of half or the whole of one or more vertebrae. Should the suppression of half a vertebra

occur in the thoracic region, there may be absence of the corresponding rib and intercostal structures on the same side. This condition may be associated with congenital dilatation of the colon. Various defects of the vascular system may also be present, such as supernumerary renal arteries accompanying a low position of one of the kidneys, or, in one case, a left-sided post-renal vena cava, associated with other anomalies of the veins, and of the nerve plexuses.

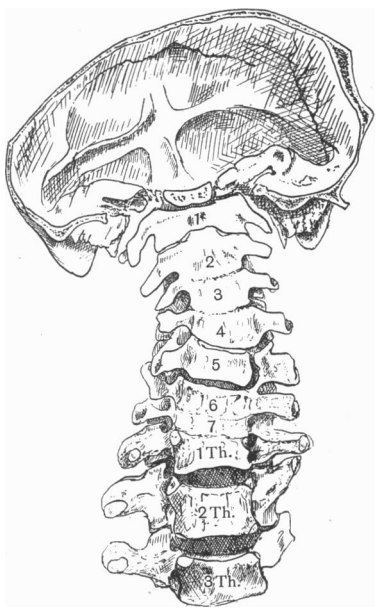

Fig. 1.

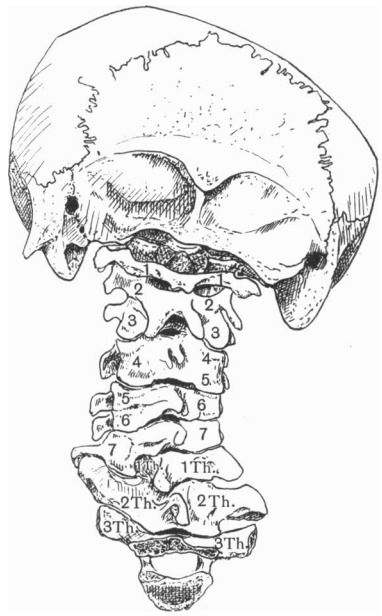

Fig. 2.

Fig. 1. Anterior aspect of the cervical and upper three thoracic vertebrae of case VIII, showing the fusion of the 2nd, 3rd, 4th and 5th cervical vertebrae, and 6th, 7th and 1st thoracic vertebrae. A pseudo-arthrosis can be seen between the body of the 5th cervical vertebra and the left half of its neural arch.

Fig. 2. Posterior view of case VIII, showing the fusion of laminae and articular processes of certain of the cervical vertebrae and secondary enlargement of the mastoid foramina.

DESCRIPTION OF CASES

Case I. Freda S., aged 1 year, was sent to hospital in 1930, because her back was bent. On examination, it was seen that the child was suffering from marked scoliosis with the summit of the convexity opposite the 9th dorsal spine. The deformity could not be corrected. Skiagrams show (fig. 3) a half vertebra in the region of the 9th thoracic vertebra on the left side. There are twelve ribs on the side of the half vertebra, and eleven only on the other.

The child was quite healthy in every other respect, and had no other congenital defects. There is no evidence of congenital deformities in the parents or their relations.

Case II. Monica T., aged 5 years and 8 months, came under observation at the age of 3, because of marked lateral curvature of the spine. She was treated

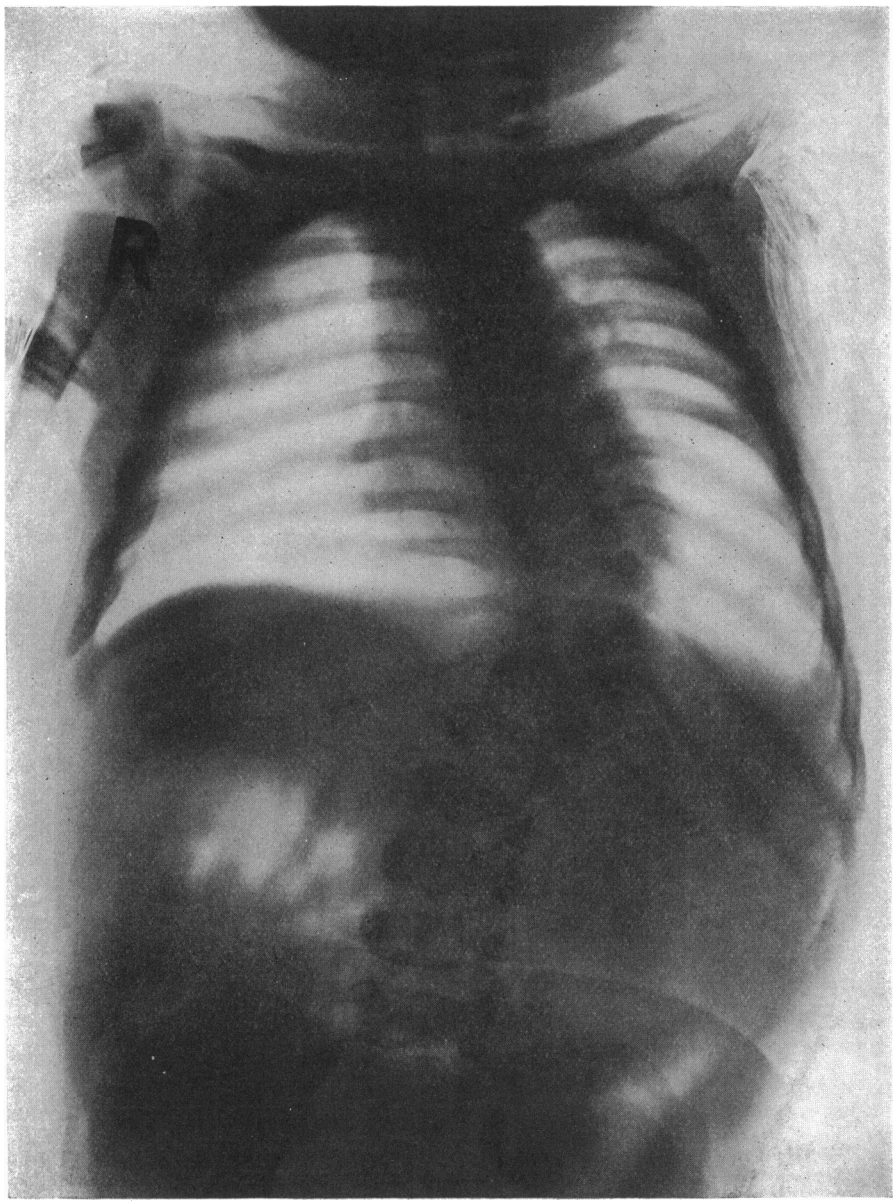

Fig. 3. Skiagram of case I, showing half vertebra in the region of the 9th thoracic vertebra, producing a scoliosis.

with a light spinal jacket. On examination, there were found severe scoliosis in the lower thoracic region, and a spina bifida occulta in the region of the 5th and 6th dorsal vertebrae. A skiagram (fig. 4) revealed half vertebrae in the region of the 2nd and 10th dorsal vertebrae. The 11th dorsal vertebra was in two parts. There was extensive malformation in the upper right ribs. The 2nd rib was absent and the 3rd bifid.

Case III. Case of bilateral cervical rib in a man aged 32, who came to hospital because of pain in the right hand, and some loss of power in the grip. He was a clerk by profession, and he noticed the pain in the hand was worse after playing tennis. On examination, the intrinsic muscles of the right hand were found to be wasted, and not so well developed as those in the left hand. The subclavian arteries could be seen pulsating in the supraclavicular fossae. On palpation, a cervical rib could easily be felt in each supraclavicular fossa. Skiagrams (fig. 5) confirmed the presence of bilateral cervical ribs, the one on the right side being more distinct. An X-ray photograph of the whole spinal column did not reveal any other abnormality. There were twelve pairs of thoracic ribs on each side.

An operation was performed in May 1922, and the right cervical rib was removed. It consisted of an osseous posterior two-thirds, and a fibrous anterior third, which was attached to the 1st thoracic rib. Recovery from symptoms was slow, and it was 6 months after the operation before all pain had disappeared, and the intrinsic muscles of the hand were equal to those on the left side. The patient has been kept under observation, has remained perfectly well, and, so far, no symptoms have been produced by the cervical rib on the left side.

Case IV. The case is somewhat similar to case III, in that bilateral cervical ribs were present, but symptoms were present on the right side only. The patient was a farmer, aged 23, who had complained of pain in the right hand for some months prior to coming under observation. On examination, there were definite wasting of the interossei muscles, and a weakness in the grip. No palpable cervical rib could be felt in the neck, but the subclavian artery appeared rather higher in the neck than normal. Skiagrams (fig. 6) revealed bilateral cervical ribs, the right one being the more conspicuous. The rest of the spinal column was normal as far as X-ray examination was concerned, there being twelve pairs of thoracic ribs on each side.

An operation was performed in December 1923, and the cervical rib was removed on the right side. The anterior half was fibrous, and pressed on the lowest brachial nerve cord. Recovery was uneventful, but it was nearly 6 months after the operation that the atrophied muscles in the hand had regained their normal tone, in spite of massage treatment. When seen 7 years after his operation, he was in good health, with no symptoms whatever. The left cervical rib had never given rise to any symptoms.

Case V. Mrs H. A., aged 21, was sent to hospital, because her left hand was becoming weaker, and she found it difficult to do her household duties, espe-

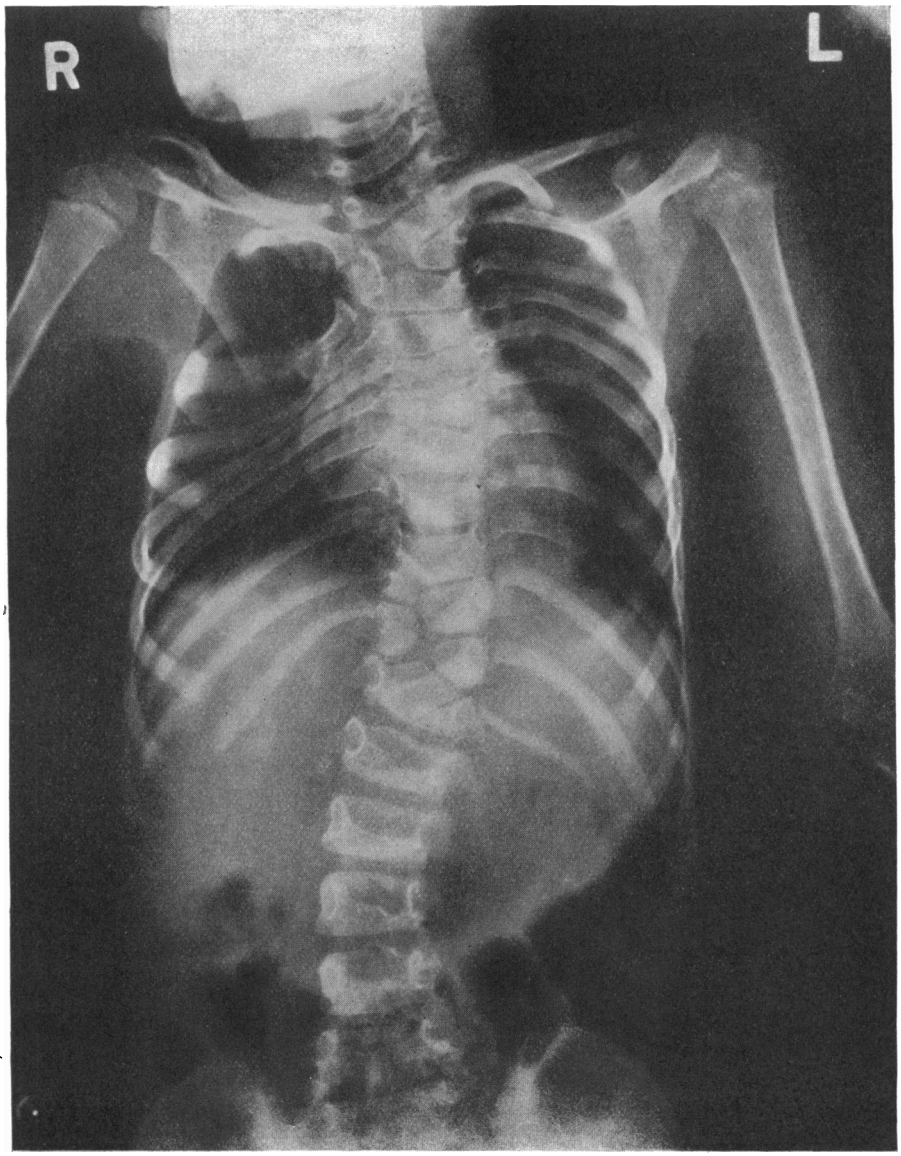

Fig. 4. Skiagram of case II, showing half vertebrae in the region of the 2nd and 10th dorsal vertebrae.

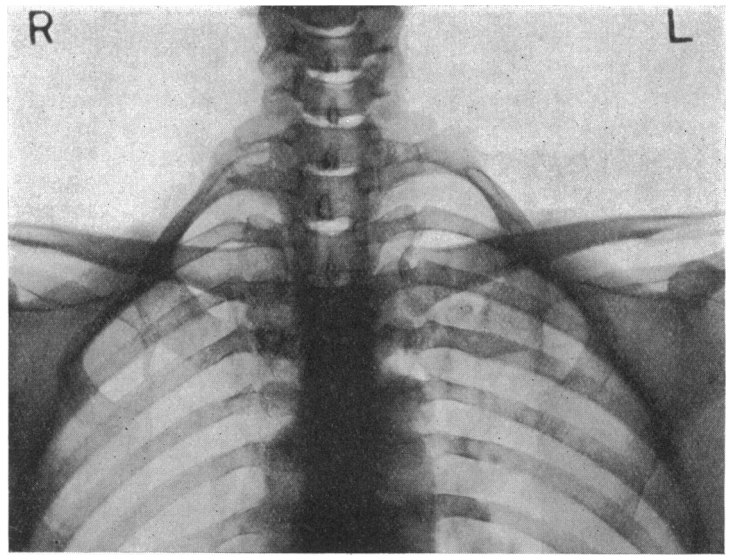

Fig. 5. Skiagram of case III, showing bilateral cervical ribs.

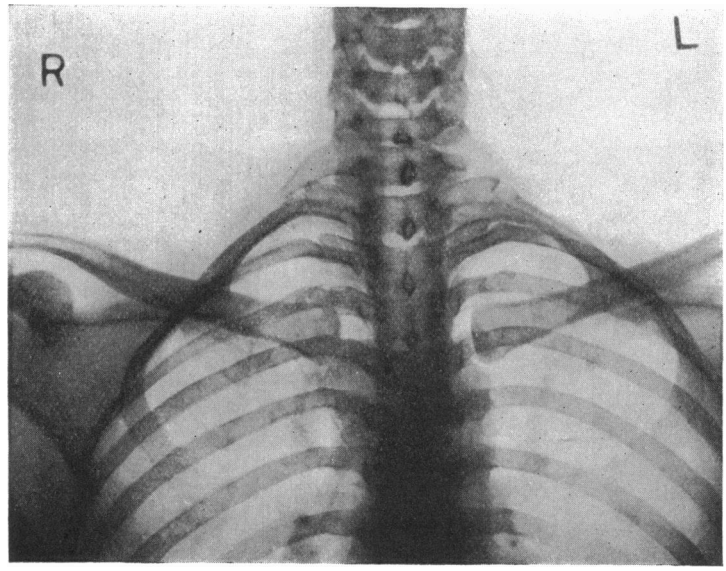

Fig. 6. Skiagram of case IV, showing bilateral cervical ribs.

cially ironing. On examination, there was distinct wasting of the interossei muscles, and definite loss of grip on the left side. No palpable tumour could be felt on either side of the neck. X-ray examination revealed a cervical rib on each side (fig. 7), that on the left being the larger. Complete X-ray examination of the spine did not demonstrate any other abnormality. There were twelve pairs of thoracic ribs on each side.

Operation for removal of the left cervical rib was carried out in March 1924. The anterior part of the rib was quite fibrous, while the posterior portion was

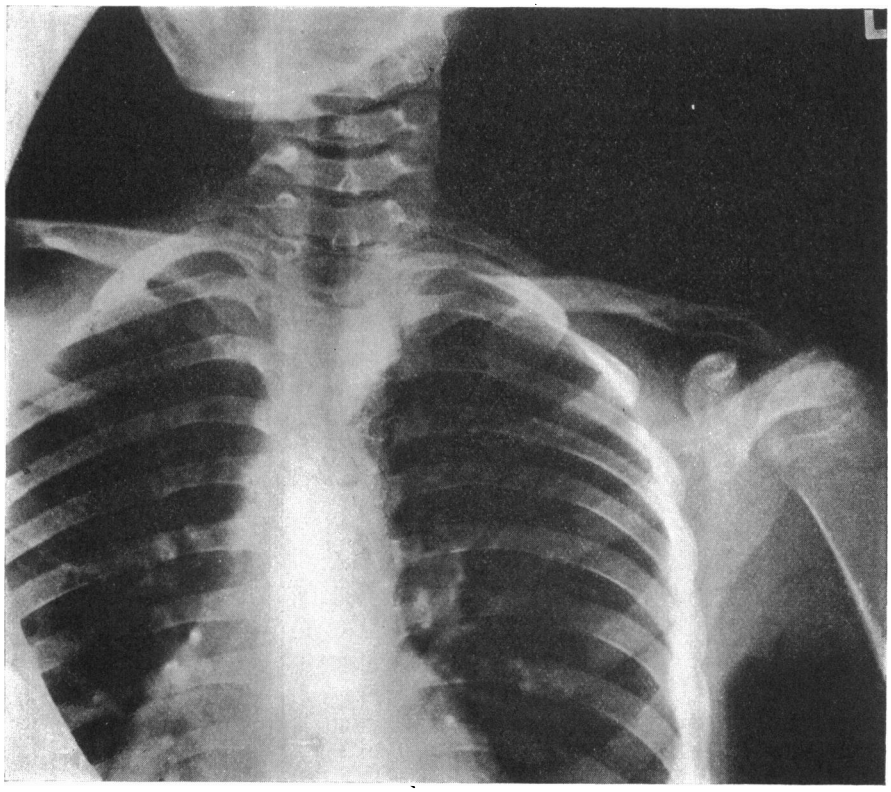

Fig. 7. Skiagram of case V, showing bilateral cervical ribs, that on the left side producing symptoms.

osseous. The patient made a good recovery, and was able to do any kind of work some 4 months after her operation. When seen 4 years afterwards, she was still in good health, and did not complain of any symptoms. In this case again, although a cervical rib was present on the right side, it did not produce any symptoms.

Case VI. This case was a man aged 24, who came to hospital complaining of pain and weakness in his right hand and arm. On examination, a very

definite cervical rib could be palpated in the right supraclavicular fossa. Skiagrams (fig. 8) revealed a very definite cervical rib, which articulated anteriorly with the 1st thoracic rib. No cervical rib was present on the left side. By X-ray examination of the whole spine, twelve pairs of thoracic ribs were seen. The cervical rib was excised in June 1925, and the patient made a complete recovery, and was able to go back to his work as a carpenter. When seen 2 years later, he was doing full work and suffering no disability.

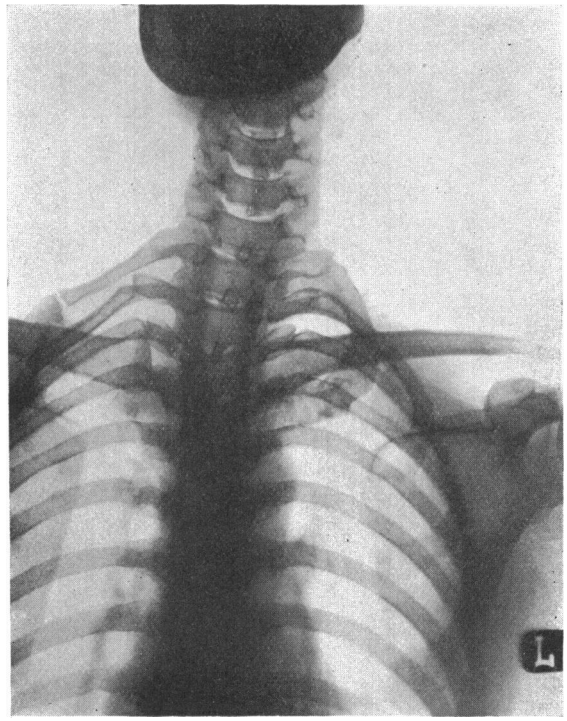

Fig. 8. Skiagram of case VI, showing cervical rib on the right side which articulated with the 1st thoracic rib.

Case VII. This case is of interest, because the body of the sternum was cleft, the ribs on each side articulating anteriorly in a sternal bar. The manubrium sterni is quite normal, and the 1st and 2nd ribs on each side articulate with it.

The child, whose present age is ten years, has been under observation since infancy, because of her chest. The photograph (fig. 9) shows the deep cleft between the anterior ends of the ribs on each side.

Case VIII. Rudimentary 1st thoracic ribs, discovered in a dissecting-room subject. The principal features of the skeleton were: a pair of rudimentary 1st thoracic ribs, each joined by a fibrous band to the pointed outer end of the 1st

costal cartilage. This articulated by its base with the lateral border of the manubrium just below the sternoclavicular joint, in the usual situation of the 1st rib cartilage; twenty-five presacral vertebrae; vertebral formula—C. 7, Th. 13, L. 5, S. 5, Co. ? 4. Thirteen pairs of ribs, including the rudimentary 1st pair; scoliosis of the vertebral column associated with irregularity and ankylosis of certain of the cervical vertebrae. The occipital bone was misshapen and asymmetrical.

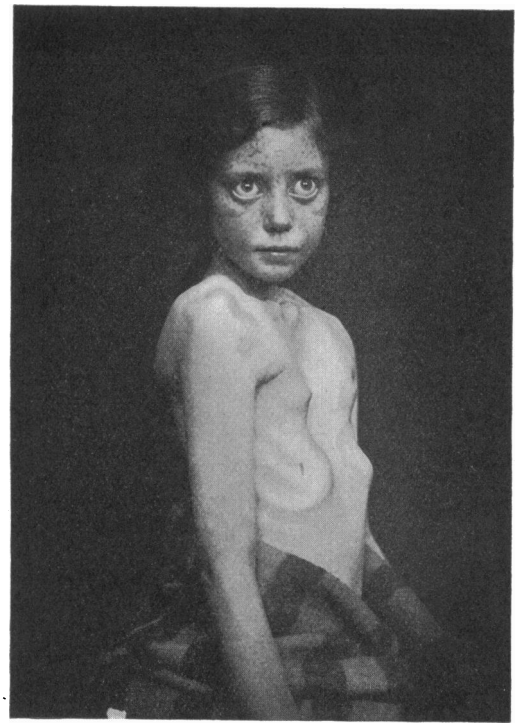

Fig. 9. Photograph of case VII, showing deformity of chest.

The subject was an adult male, who was certified to have died from bronchitis and tuberculous disease of the vertebral column. On enquiry into the history of his illness it was ascertained that no symptoms were complained of which would indicate injurious pressure by the abnormal ribs on either nerve cords or vessels. The head and upper part of the cervical segment of the vertebral column were inclined to the left, there being a curve with the convexity to the right at the junction of the neck with the thorax. Below this level the bodies of the vertebrae inclined to the left, the axis of the column returning to the median plane, and a compensatory bend being present in the lower thoracic region with the convexity to the left. Owing to the deformity of the vertebral column and ribs, the heart was displaced to the right, its apex lying behind the

body of the sternum, while the whole of the right lung was compressed between the thoracic wall laterally, and the vertebral column and mediastinal structures medially. The right pleural cavity contained a considerable quantity of inspissated pus. The ductus arteriosus was incompletely obliterated, there being a narrow channel which just admitted a small bristle. The endothelium lining the vestibule of the left auricle was roughened by calcareous deposits.

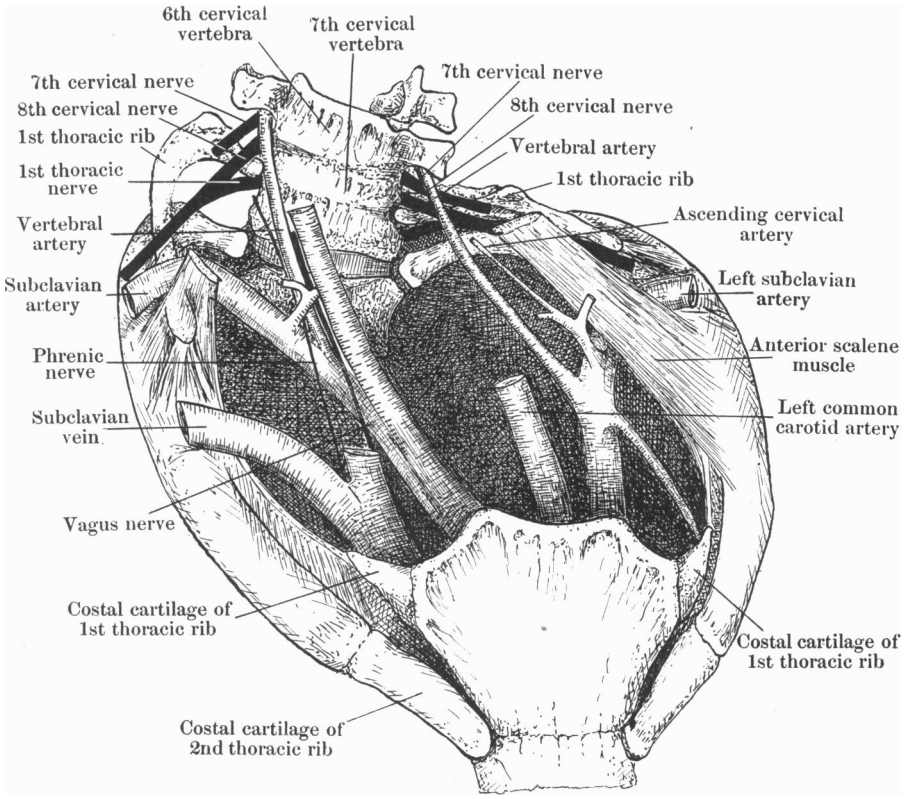

Fig. 10. Case VIII. Drawing showing bilateral rudimentary 1st thoracic rib.

The spleen was much enlarged. The left kidney was considerably lower than normal, and two accessory renal arteries entered its upper pole.

The rudimentary 1st rib of the right side, fig. 10, articulated with the body and transverse process of the 8th vertebra (presumably the 1st thoracic vertebra). The rib was so highly curved that its chord, measured from head to tip, was 4·2 cm., while the measurement along its convex border was 8 cm. The shaft of the rib ended in a blunt process which was connected by a fibrous band with the 2nd thoracic rib, and the tip of the 1st costal cartilage. This cartilage was triangular in shape, its base being attached to the lateral angle of the manubrium in the usual situation of the 1st rib cartilage, and its apex continuous with the fibrous cord. The inner border of the rib at the junction of the

neck with the shaft and the adjacent part of the upper surface of the shaft was rough for the attachment of the scalenus medius muscle. Owing to the curve of the upper cervical vertebrae to the left, the right vertebral artery as it coursed up to the foramen in the transverse process of the 6th cervical vertebra lay just medial to the head of the rudimentary rib, and the right phrenic nerve, which was also deflected medially, crossed in front of the neck of the rib. The subclavian artery on the right side crossed the shaft of the 1st thoracic rib in front of the scalenus medius muscle, and the lower primary trunk of the brachial plexus. The artery lay behind the attachment of the anterior scalene muscle to the tip of the rib and the fibrous band which was prolonged forward from this to the 1st costal cartilage. The subclavian vein crossed the fibrous band and 2nd rib in front of the scalenus anterior, and beyond the tip of the 1st rib. Some of the superficial fibres of both the scalenus anterior and the scalenus medius muscles passed over the 1st rib and gained attachment to the 2nd rib. Fibres representing the external and internal intercostal muscles also passed between the 1st rib with its fibrous prolongation and the 2nd rib.

The 2nd right rib was long and placed very obliquely. It had the usual characters of a 2nd thoracic rib, and its cartilage joined the sternum at the junction of the manubrium with the body. The cartilage did not, however, pass horizontally inward to join the sternum, but approached the joint obliquely, turning downward from the thoracic inlet to the sternal angle, fig. 10. The 2nd rib thus appears to have been displaced upwards to compensate for the rudimentary condition of the 1st rib. The chord of the 2nd rib, measured from head to tip of costal cartilage, was 13·5 cm., and the measurement along its convex border, 21·5 cm. (8 in.).

The rudimentary 1st thoracic rib of the left side had very similar relations to those of the right. Its vertebral end articulated with the body and transverse process of the 8th vertebra, and its tip was connected by a fibrous cord with the pointed outer end of the 1st costal cartilage. Its tubercle articulated, however, with the transverse process of the 7th cervical vertebra as well as with that of the 8th vertebra. Owing, moreover, to the curvature of the vertebral column, the 1st left rib was not so highly curved as the 1st right rib, and the lower primary trunk of the brachial plexus passed outward below the level of the rib before crossing over the fibrous band, instead of bending over the rib, as on the right side. The subclavian artery also crossed the fibrous band and the 2nd rib beyond the tip of the 1st rib. The subclavian vein on both sides crossed over both the 2nd rib and the fibrous continuation of the 1st rib. The vertebral artery on the left side crossed in front of the neck of the rudimentary rib. The middle and upper primary trunks of the brachial plexus were situated immediately above the 1st rib, and lay in front of the middle scalene muscle, which was attached to the posterior part of the shaft of the 1st rib. The subclavian artery passed through the fibres of the anterior scalene muscle, some of which were attached to the tip of the 1st rib and adjacent part of the 2nd rib and others to the fibrous band, in front of the artery, between it and the vein.

Base of the skull

Intracranial aspect. The region around the foramen magnum and the adjoining parts of the petrosal elements of the temporal bones, appeared to have been pushed upwards from below into the cranial cavity, as if pressure on the head had been exerted in a downward direction against the resistance of the vertebral column pushing upwards from below, the base of the skull having yielded to the pressure and the counter-pressure.

The antero-posterior diameter of the foramen magnum was thus reduced from the normal 3·7 cm. to 2·3 cm., the greatest transverse diameter being 2·7 cm. The anterior condylar foramina were much reduced in size. The clinical history of the case, however, did not give any evidence of interference with the motor supply of the tongue. The odontoid process lay in a recess beneath the basioccipital and was overlapped on each side by the anterior margin of the foramen magnum. The left jugular foramen was almost obliterated; it transmitted the 9th, 10th and 11th cranial nerves, but neither the sigmoid sinus nor the inferior petrosal sinus passed through it. The blood from the sigmoid sinus on the left side being unable to leave by the jugular foramen, appears to have escaped through a much enlarged mastoid foramen, fig. 2. A similar large mastoid foramen was present on the right side, but the venous parts of the right jugular foramen were not obliterated, and both the inferior petrosal sinus and the main stream from the sigmoid sinus appear to have left the skull through this foramen. The groove for the sigmoid sinus on the left side was situated entirely on the temporal bone, the petro-occipital suture lying 0·5 cm. behind it. The central part of the petrosal element of each temporal was so curved upward as to form two prominences in the base of the skull.

Extracranial aspect. The region around the margin of the foramen magnum was hollowed in correspondence with the projection of the same region in the interior. There was a raised ridge round the lateral and posterior boundaries of the foramen magnum like that seen in cases of manifestation of the neural arch of an occipital vertebra. There were no posterior condylar foramina. The bone forming the floor of the cerebellar fossa on each side was extremely thin and translucent.

The cervical vertebrae

The atlas vertebra was smaller and more slender than the normal bone. Owing to the upward displacement of the central part of the bone into the hollow on the under-surface of the occipital bone, the transverse processes sloped obliquely downwards.

The axis, 3rd, 4th and the greater part of the 5th cervical vertebrae were fused into a single piece, figs. 1 and 2. This piece articulated with a block formed by the left half of the neural arch of the 5th cervical vertebra and the 6th, 7th and 8th vertebrae. An accessory joint, see fig. 1, was formed between these two blocks.

Case IX. Bilateral cervical ribs found in an aged female dissecting-room

subject. The atlas was fused with a partially separated occipital vertebra, and there was considerable asymmetry and obliquity of the upper cervical vertebrae and skull, the left transverse process of the atlas being half an inch lower than the right. A detailed description of the atlas and occipital bone of this case has been previously described by one of us, R. J. G., and Erichsen Powell in this *Journal* (1915). It serves as an illustration of variations in the vertebral column taking place in two directions, namely, shortening of the cervical region at the upper end by fusion of the atlas with an occipital vertebra, and at the lower end by the development of a pair of ribs on the 7th cervical vertebra. It is also an example of the co-existence in the same subject of manifestation of an occipital vertebra and fusion of the atlas with this vertebra and thus with the base of the skull.

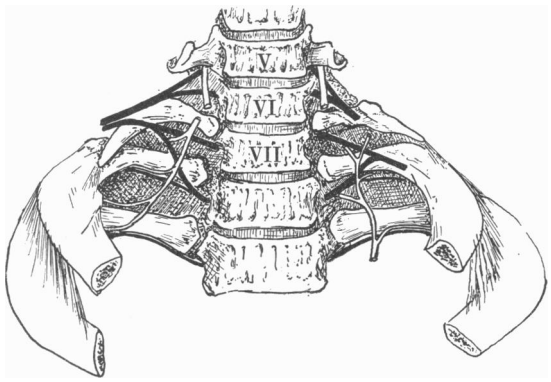

Fig. 11. Case IX. Drawing showing relation of nerves and vessels to cervical ribs.

The right cervical rib of this woman was 5 cm. long. It articulated by its head, with the body of the 7th cervical vertebra, and by its tubercle with the transverse process of the same vertebra. Its shaft was crossed obliquely on its upper surface by the lower primary trunk of the brachial plexus (fig. 11). This was formed by the union of the anterior primary divisions of the 8th cervical and 1st thoracic nerves. Above and behind this trunk was a trunk formed by the union of the 6th with the 7th cervical nerves. The subclavian artery crossed the rib in front of the lower primary trunk, and the subclavian vein passed over a fibrous cord which joined the tip of the cervical rib with the 1st thoracic rib. The costo-cervical artery on both sides of the body descended in front of the neck of the cervical rib. It then gave off the deep cervical branch which passed as usual in a backward direction between the transverse process of the 7th cervical vertebra and the neck of the 1st thoracic rib. Its intercostal branch on the right side descended in front of the 1st and 2nd thoracic ribs, and supplied the 1st and 2nd intercostal spaces. On the left side these spaces were chiefly supplied by an ascending branch from the aorta. This anastomosed in the 1st thoracic intercostal space with the left superior intercostal artery. The

vertebral artery on both sides entered the foramen transversarium of the corresponding side of the 5th cervical vertebra.

The left cervical rib was 3·5 cm. long, and deeply grooved on its upper surface by a nerve trunk formed by the union of the anterior primary divisions of the 6th and 7th cervical nerves. The lower primary trunk formed by the union of the 8th cervical and 1st thoracic nerves lay entirely below the cervical rib and crossed a fibrous cord which connected its tip with the 1st thoracic rib. The subclavian artery and the subclavian vein crossed the first thoracic rib in front of the cervical rib.

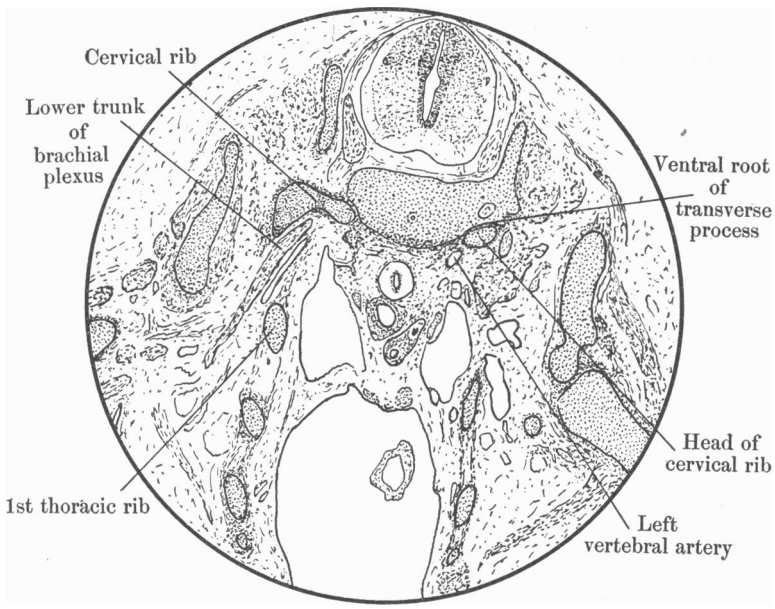

Fig. 12. Transverse section through a 19 mm. human embryo, showing the vertebral ends of a pair of 7th cervical ribs. On the left side, the ventral root of the transverse process of the 7th cervical vertebra is seen to be formed independently of the head and neck of the cervical rib.

Case X. Bilateral cervical ribs in a human embryo 19 mm. in length. This specimen was obtained by one of us, C. P. G. W., at a laparotomy, and is in excellent condition. The sections were made transversely. Differentiation of the gonads and adnexa was sufficiently advanced to recognise the sex as being female. The cervical rib on each side extended about one-third the distance from the vertebral column to the sternal bar of the corresponding side.

On the right side the ventral end of the cervical rib tapered to a point, which was connected to the cartilage of the 1st thoracic rib by a band of condensed mesoderm. It articulated by its head with the body of the 7th cervical vertebra and by its tubercle with the transverse process of this vertebra. A complete foramen transversarium was present in the transverse process of the 7th cervical vertebra on both sides, its anterior boundary being formed by a

cartilaginous bridge, continuous with the cartilage of the centrum medially and with the transverse process dorso-laterally, fig. 12; the foramen on each side transmitted a small vein. The anterior tubercle and the cartilaginous bridge forming the anterior wall of the foramen were separated from the head and neck of the cervical rib by perichondrial mesoderm, and the two structures were quite independent. The vertebral end of the left cervical rib had similar relations to that of the right, but the cartilage of its shaft was directly continuous at its ventral end with that of the 1st thoracic rib, fig. 13.

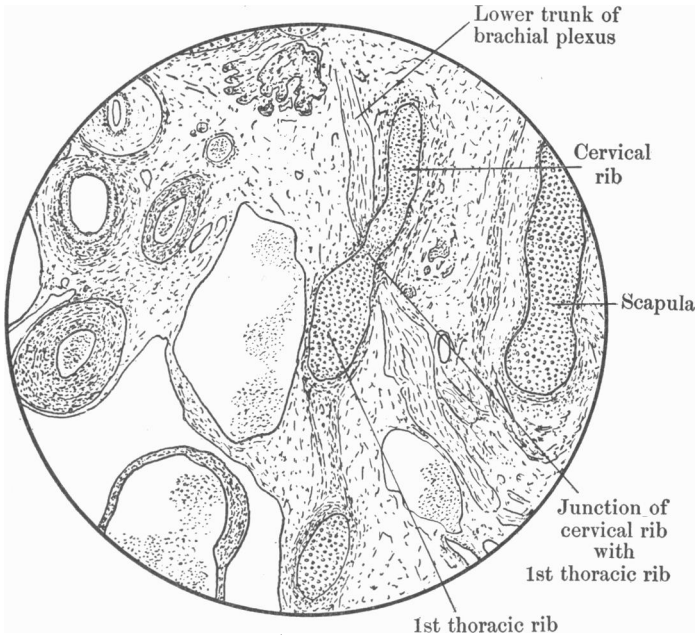

Fig. 13. Transverse section through the same embryo as fig. 12, showing the ventral end of the left cervical rib at its point of union with the 1st thoracic rib. It is probable that the continuity of the cartilage of the two ribs has been established secondarily.

The lower primary trunk of the brachial plexus on the right side crossed the cervical rib near its tip. It was formed by the junction of the anterior primary divisions of the 8th cervical and the 1st thoracic nerves. The subclavian artery and vein crossed the 1st thoracic rib, in front of the cervical rib. The first serration of the serratus anterior muscle as well as the scalenus medius muscle were attached to the cervical rib. The scalenus anterior was attached to the 1st thoracic rib in the usual situation between the subclavian arteries and veins. On the left side the general relations of the cervical rib were similar to those on the right, but the lower primary trunk of the brachial plexus crossed over the cartilaginous bar, which joined the sternal end of the cervical rib with the 1st thoracic rib.

There were eleven pairs of thoracic ribs, and six lumbar vertebrae. The vertebral arteries on each side entered the foramen transversarium on the corresponding side of the 6th cervical vertebra.

Variations of the transverse process of the 7th cervical and 1st dorsal vertebrae in the adult have been described by Duckworth and Dwight in the human subject, and by Bradley and Gorton in the horse. In the human embryo similar variations of the transverse processes of these vertebrae are also frequent. The 7th cervical vertebra, however, normally bears the cartilaginous rudiment of a cervical rib on each side. This rudiment, which represents merely the head, neck and tubercle of a cervical rib, frequently persists, as Struthers has shown, in the adult, but on account of its small size remains unrecognised. On the other hand, in the majority of cases, the rudiment either disappears by atrophy, or becomes fused with the transverse process.

The presence in the embryo of well-developed cervical ribs, with shafts extending forward towards the sternum, appears to be as unusual as it is in the adult. If this human embryo (case X), in which two well-developed cervical ribs were present, had survived, we consider that these ribs would have become ossified and remained in the adult in much the same condition as regards their relative size and relations, as they were in the embryo. There would have been a so-called "bicipital rib" on the left side, and a cervical rib of medium size ending in a fibrous band on the right side.

The anterior (costal) parts of the transverse processes of the upper cervical vertebrae are normally chondrified by an extension of the process of chondrification, from the true transverse process, joining the cartilage of the centrum, and an examination of the material which we have at our disposal shows that this is usually the case also in the 6th and 7th cervical vertebrae.

It is extremely improbable that the presence of well-developed cervical ribs in the adult is due, as has been suggested, to an arrest of the normal process of atrophy of embryonic cervical ribs, since the cervical ribs which are present in the embryo are a mere rudiment, and seldom extend beyond the tip of the transverse process. It is possible, however, that some cases of rudimentary 1st thoracic ribs may be due to atrophy of the central portion of a 1st thoracic rib, produced, as was suggested by Wood Jones, by pressure of the lower primary trunk of the brachial plexus, upon the developing rib. The close relationship of the roots of the brachial plexus to the 1st thoracic rib is well seen in fig. 14, which represents the condition found in the human embryo at the end of the 7th week of gestation. The part of the rib which is absent, however, is often much more extensive than could be accounted for, in this way, and on the other hand, cases occur in which the part of the rib which is crossed by the lower primary trunk is present and the anterior part only is missing.

Theories put forward in explanation of variations in the number and position of the ribs, and of meristic variations of the vertebral column

(1) *The ribs and pelvis are moved headward along the vertebral column, or in the reverse direction—tailward,* the total number of vertebrae remaining the same, but individual vertebrae are modified in adaptation to the changed position of the ribs or pelvis; the lumbo-sacral and brachial plexuses are also

assumed to be shifted forward (*pre-fixed type*), or backward (*post-fixed type*).

(2) *There is a tendency in Man and the higher Primates towards reduction in the number of ribs*, rudimentary 1st thoracic ribs or suppression of the last thoracic ribs being regarded as *progressive variations*, cervical ribs or lumbar ribs as *atavistic variations*.

(3) *Variations about a mean* which affect chiefly the transitional segments. When a vertebra of one region, such as the thoracic, assumes the special charac-

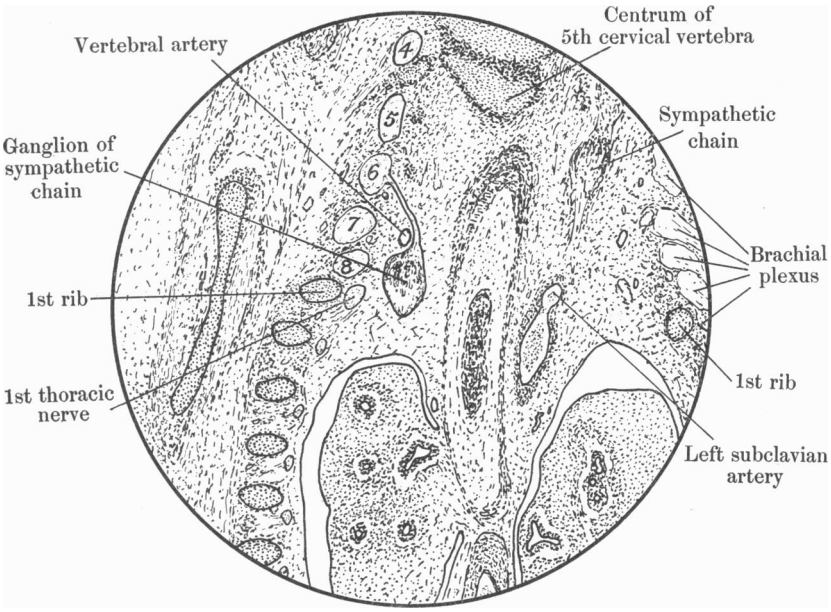

Fig. 14. Coronal section through a 20 mm. human embryo, showing the close relationship of the roots of the brachial plexus to each other, and the relation of these to the 1st thoracic rib.

ters of the region in front, e.g. the cervical, the variation was classed by Bateson as being a "*forward homoeosis*." When the vertebra of a particular region assumes the character of the vertebrae situated behind it, the condition is a "*backward homoeosis*"; thus, if the last pair of ribs is suppressed, the 12th thoracic vertebra will assume the characters of a lumbar vertebra (backward homoeosis); the development of a pair of cervical ribs is also an instance of backward homoeosis, the 7th cervical vertebra assuming the characters of a thoracic vertebra. The suppression of the 1st thoracic ribs is an example of forward homoeosis. Other examples of these changes will be given later, with reference to the bearing of this conception on the etiology of the variations.

(4) *The intercalation* of an additional vertebra and ribs between any two of a series, or *excalation*, of a vertebra with its accompanying costal elements

In other words, addition to the total number, or suppression of one or more segments.

(5) *Irregularity in the cleavage* or segmentation of the body.

(6) *Fusion of segments*, as is common in the cervical region in cases of cervical ribs and rudimentary 1st thoracic ribs, and in cases of defective development of the vertebral column in teratological specimens.

In considering the causes of the changes met with in the adult skeleton, it must be remembered that some of these are secondary adaptive changes which have been brought about by attempts on the part of the organism to overcome the effects of the primary defect, e.g. compensatory curves of the vertebral column in congenital scoliosis produced by the suppression of half a vertebra, or modification of the atlo-axoidean articulation, to compensate for the loss of movement which results from fusion of the atlas with the occipital bone.

We have, however, been impressed in the study of these cases by the extreme frequency of defects of development, in association with cervical ribs and rudimentary 1st thoracic ribs, occurring in other regions of the body. These defects are not always directly dependent on the presence or absence of the ribs in question, or the accompanying variations in the vertebral column or spinal nerves, and it seems probable that there is a common cause which has produced an unstable condition of the body and which has affected the development of the skeletal and other systems. In other words a tendency to vary has been produced. A very considerable number of these variations come into the category of defective developments, and if, as seems probable, this is the true explanation of their occurrence, it is hardly conceivable that progressive evolution could take place by such irregular changes as are commonly met with in these cases. Many of the changes are obvious defects in development, and are sometimes incompatible with life, e.g. rachischisis or anencephalus.

Rudimentary 1st thoracic ribs may generally be distinguished from cervical ribs by paying attention to the following points, though it must be borne in mind that there are exceptions to the general rule, and that in some anomalous cases the right and left sides do not correspond, and that there may be a general irregularity and want of symmetry.

Facts that may be ascertained by X-ray examination:

Rudimentary 1st thoracic ribs

(1) Seven cervical vertebrae above the rudimentary 1st rib.

(2) The rib next below the rudimentary rib is long, and resembles a normal 2nd thoracic rib. Its length, including the costal cartilage being approximately 21 cm.

(3) The costal cartilage of a rudimentary 1st thoracic rib may be present as a separate part which articulates with the lateral angle of the manubrium in the ordinary situation of the 1st rib cartilage.

7th cervical ribs

(1) Six cervical vertebrae above the 1st rib.

(2) The rib next below the 1st rib is short and highly curved, and is more horizontally placed than is the 2nd rib in defective development of the 1st thoracic rib.

(3) A cervical rib rarely reaches the sternum, and if its tip does not end freely, it is joined to the 1st thoracic rib or its cartilage by a fibrous band, bone or cartilage.

Rudimentary 1st thoracic ribs

(4) The cartilage of the 2nd rib articulates either with the side of the manubrium, or joins the sternum at the joint between the manubrium and the body of the sternum.

(5) The cartilage of the 3rd rib usually joins the sternum below the level of the sternal angle, but the manubrium may be unusually long (7–8 cm.), owing to the inclusion in it of the 1st segment of the mesosternum, and it will then be joined on each side by three rib cartilages.

(6) Frequently eight pairs of rib cartilages articulate with the sternum.

(7) Twelve pairs of ribs are commonly present: occasionally thirteen.

(8) There may be twenty-five pre-sacral vertebrae, or the 1st sacral vertebra may be partially separated, and resemble a normal 5th lumbar vertebra.

7th cervical ribs

(4) The cartilage of the 2nd rib joins the lateral angle of the sternum in the usual situation of the cartilage of the 1st thoracic rib.

(5) The cartilage of the 3rd rib usually joins the sternum at the level of the sternal angle. If the 7th cervical rib is fully developed, three rib cartilages may articulate with a manubrium of normal length.

(6) Seven pairs of rib cartilages usually articulate with the sternum.

(7) Thirteen pairs of ribs are commonly present: in about one-third of the total number of cases twelve pairs are present. The last thoracic ribs are sometimes rudimentary, or may be absent.

(8) Usually twenty-four pre-sacral vertebrae.

Homoeotic variations

Bateson distinguished a separate group of variations, which he termed "homoeotic." In this category, one member of a meristic series assumes the form or characters proper to other members of the series, e.g. a cervical vertebra may bear ribs, and assume the characters of a dorsal vertebra. There is a substantive variation in the segment, but no alteration of its position in the series or in the total number of vertebrae. With reference to the vertebral column, the homoeosis may be in a forward direction towards the head or in a backward direction towards the tail end of the body. Thus Bateson distinguishes two types of homoeosis in the vertebral column:

(1) The alteration occurs in a direction from behind forwards—*Forward Homoeosis.*

(2) The alteration occurs in a direction from before backwards—*Backward Homoeosis.*

Examples of forward homoeosis:

Cervical to cranial	...	Fusion of atlas with occipital bone.
Dorsal to cervical	...	Rudimentary 1st thoracic rib.
Lumbar to dorsal	...	Lumbar ribs.
Sacral to lumbar	...	Liberation of 1st sacral vertebra.
Coccygeal to sacral	...	Fusion of 1st coccygeal vertebra with sacrum.

Examples of backward homoeosis:

Cranial to cervical	...	Manifestation of occipital vertebra.
Cervical to dorsal	...	Cervical ribs.
Dorsal to lumbar	...	Absence of 12th thoracic ribs.
Lumbar to sacral	...	Fusion of 5th lumbar vertebra with sacrum.
Sacral to coccygeal	...	Liberation of 5th sacral vertebra.

The terms employed in the examples cited are those which are most commonly used to designate the conditions described, and the authors wish it to be clearly understood that they do not want any inferences to be made from the suggestion indicated by the name of the cause of any particular variation, e.g. the term "sacralisation" of the 5th lumbar vertebra is more in accord with Bateson's description than the term usually employed to denote this condition, viz. fusion of the 5th lumbar vertebra with the sacrum.

In the case of suppression or rudimentary condition of the 1st thoracic ribs, the 1st thoracic vertebra assumes the characters of a 7th cervical, and the homoeosis is thus in a forward direction. In cervical ribs, the 7th cervical vertebra assumes the characters of the vertebra in the region next behind, namely, the 1st dorsal, and the homoeosis is thus backward.

The cases of cervical rib, rudimentary 1st thoracic rib and other variations in the number and position of the ribs which have been included in the following table, have for the most part been collected without selection from the cases published in the *Journal of Anatomy and Physiology*, and this *Journal* for a period of nearly 50 years, and though from the statistical standpoint their number may appear small, they are mostly cases in which the number of the ribs and their relation to the vertebrae have been described. They are therefore of much greater value than the records of a large number of clinical cases, in which the exact position of the abnormal rib or ribs relative to the vertebral column has not been stated. Four clinical cases in which scoliosis was present have been included, and also some anatomical cases, in which the whole of the vertebral column and ribs were not present. The authors, however, consider that these cases will help to substantiate rather than detract from, the value of the conclusions drawn from the more complete reports.

A short summary of associated conditions which have been present in the cases of congenital abnormalities of the ribs, is shown in the right-hand column of the following table. This clearly indicates the frequency with which defects, such as irregular formation of the vertebrae with congenital ankylosis and scoliosis, of the vertebral column, accompany the occurrence of cervical ribs, rudimentary 1st thoracic ribs, and other congenital variations in the number of the ribs.

The percentage frequency with which the defects mentioned below are associated with congenital variations in the number and position of the ribs, as recorded in the 70 cases which are reported, is 47·14; and the percentage frequency of cases in which it is definitely stated that spinal curvature or "scoliosis" was present, is 21·43. These figures are far too large to be explained by the assumption that a chance association of the two conditions has taken place, and a perusal of the total number of cases reported suggests that the abnormalities of the ribs and the associated defects may be related. These associated conditions belong to the category of defects of development, and include deformities, such as asymmetry of the face, cleft palate, hydrocephalus, spina bifida, talipes, fusion and irregularity of the ribs, asymmetry

Table I. *Table showing the frequency with which anomalies in the development of the ribs are associated with irregular segmentation of the vertebral column and other defects of development. The table also indicates the number of vertebrae in the regions denoted by the letters* C., *cervical;* T., *thoracic;* L., *lumbar;* S., *sacral. The position and number of the ribs on each side is also shown, and the number of ribs articulating with the sternum, when this has been recorded.* V., *vertebrae;* L.R., *left ribs;* R.R., *right ribs;* (*l.r.*), *rudimentary* 1*st thoracic rib;* + *unnumbered additional vertebrae;* M., *male;* F., *female*

Author		C.	T.	L.	S.	Total no. of ribs	No. of sternal ribs	Sex	Deformations
Addison	V.	7	12	—	—	—	—	F.	Costal cartilages of 1st thoracic ribs attached to side of manubrium, below a bony process at the lateral angle for the cervical rib
	L.R.	7th C.	12	—	—	13	—		
	R.R.	7th C.	12	—	—	13	—		
Babcock	V.	7	12	—	—	—	—	—	Scoliosis. Wasting and ischaemia. Asymmetry of face. Gangrene of fingers
	L.R.	—	12	—	—	12	—		
	R.R.	7th C.	12	—	—	13	—		
Barclay-Smith	V.	8	12	5	5	—	—	F.	Atlas fused with occipital bone. Axis and 3rd cervical vertebrae fused. 1st sacral vertebra partially lumbarised. Various minor malformations
	L.R.	8th C.	12	—	—	13	—		
	R.R.	—	12	—	—	12	—		
Bateson	V.	7	11	5	5	—	—	F.	5th and 6th cervical vertebrae partially ankylosed. 23 pre-sacral vertebrae
	L.R.	7th C.	11	—	—	12	—		
	R.R.	7th C.	11	—	—	12	—		
Bateson	V.	7	11	5	5	—	—	M.	23 pre-sacral vertebrae
	L.R.	7th C.	11	—	—	12	—		
	R.R.	7th C.	11	—	—	12	—		
Bellamy	V.	7	12	6	5	—	—	—	25 pre-sacral vertebrae. 1st thoracic ribs rudimentary. Quadratus femoris muscle absent
	L.R.	—	12(*l.r.*)	—	—	12	—		
	R.R.	—	12(*l.r.*)	—	—	12	—		
Black	V.	7	12	5	5	—	—	F.	
	L.R.	7th C.	12	—	—	13	—		
	R.R.	7th C.	12	—	—	13	—		
Brash	V.	6½	13	5	5	—	—	M.	Fusion and irregularity of cervical vertebrae. Ankylosis of thoracic vertebrae. Absence of half a vertebra in cervical region, with associated defect of spinal cord and absence of spinal nerves. Addition of whole segment in thorax
	L.R.	—	13	—	—	13	—		
	R.R.	—	13	—	—	13	—		

Table I (*continued*)

Author		C.	T.	L.	S.	Total no. of ribs	No. of sternal ribs	Sex	Deformations
Cleland	V.	6	12	6	—	—	—	F.	Cervical spina bifida. Cleft palate. Dorsal and cervical vertebrae much altered. Mesial gap between right and left halves of bodies of vertebrae, extending from 7th cervical vertebra up to axis. Fusion of laminae from 2nd to 5th cervical vertebrae
	L.R.	—	12	—	—	12	—		
	R.R.	—	12	—	—	12	—		
Dagnini	V.	7	12	—	—	—	—	M.	Head held at slight angle to prevent pain. Vasomotor disturbances due to pressure. Right arm and right cheek abnormally hot
	L.R.	7th C.	12	—	—	13	—		
	R.R.	7th C.	12	—	—	13	—		
De Vernejoul et Chauvin	V.	7	12	—	—	—	—	—	Scoliosis in cervico-dorsal region
	L.R.	7th C.	12	—	—	13	—		
	R.R.	—	12	—	—	12	—		
Dow (A)	V.	7	12	5	5	—	—	M.	Cartilages of 2nd thoracic ribs attached obliquely along the lateral border of the manubrium
	L.R.	—	12(*l.r.*)	—	—	12	—		
	R.R.	—	12(*l.r.*)	—	—	12	—		
Dow (B)	V.	7	12	—	—	—	—	—	Cartilages of 2nd thoracic ribs attached to lateral border of manubrium. Right vertebral artery entered transverse process of 5th cervical vertebra
	L.R.	—	12(*l.r.*)	—	—	12	—		
	R.R.	—	12(*l.r.*)	—	—	12	—		
Dukes and Owen	V.	7	12	5	—	—	—	—	2nd and 3rd cervical vertebrae fused. Costal element of transverse process of atlas ligamentous on right side
	L.R.	—	12(*l.r.*)	—	—	12	—		
	R.R.	—	12(*l.r.*)	—	—	12	—		
Dwight (A) Class III, Group C, V. fulcralis, 27	V.	7	13	6	5	—	—	—	Ribs 1–3 fused. Marked scoliosis. Laminae of cervical vertebrae very much distorted, several mingling together with their neighbours of the same side and not being opposite their fellows. 6th lumbar vertebra partially sacralised
	L.R.	—	13	—	—	13	—		
	R.R.	—	13	—	—	13	—		
Dwight (B) Class III, Group C, V. fulcralis, 27	V.	7	13	6	5	—	—	M.	Axis fused with 3rd cervical vertebra. Laminae so fused that it must be considered a congenital condition. 6th lumbar vertebra partially sacralised
	L.R.	—	13	—	—	13	—		
	R.R.	—	13	—	—	13	—		
Dwight (J) Class IV, Group C, H 3	V.	6	12	6	6	—	—	F.	Last lumbar vertebra sacralised on left side. Atlas and axis fused. 6th cervical vertebra resembles normal 7th. 7th cervical vertebra resembles normal 1st thoracic. Right 1st rib resembles normal 1st thoracic rib
	L.R.	—	12(*l.r.*)	—	—	12	—		
	R.R.	—	12(*l.r.*)	—	—	12	—		
Dwight	V.	7	12	5	6	—	—	—	4th and 5th cervical vertebrae fused. Irregularity and asymmetry
	L.R.	7th C.	12	—	—	13	—		
	R.R.	7th C.	12	—	—	13	—		

Table I (*continued*)

Author		C.	T.	L.	S.	Total no. of ribs	No. of sternal ribs	Sex	Deformations
Dwight	V.	7	12	—	—	—	—	—	Atlas and axis vertebrae fused. Irregularity of vertebrae
	L.R.	7th C.	12	—	—	13	—		
	R.R.	7th C.	12	—	—	13	—		
Edington	V.	7	11½	—	—	—	—	M.	Atresia ani. Absence of left kidney and ureter. Right alveolo-labial hare lip. Dwarfing of right thumb. Scoliosis. Fusion of vertebrae. Absence of right half of centrum of 5th thoracic vertebra. Fusion and irregularity of thoracic ribs. 6th and 7th left cervical ribs. 7th right cervical rib
	L.R.	6 and 7	12	—	—	14	9		
	R.R.	7	11	—	—	12	8		
Gaucher et Crouzon	V.	7	12	—	—	—	—	—	Congenital syphilis. Premature birth. Wassermann + History of miscarriages in mother. Deafness. Interstitial keratitis. Peri-orbital pains
	L.R.	7th C.	12	—	—	13	—		
	R.R.	7th C.	12	—	—	13	—		
Gladstone and Wakeley	V.	7	13	5	5	—	—	M.	Fusion of cervical vertebrae 2–7 and 5–7. Scoliosis. Asymmetry and irregularity of skull. Supernumerary renal vessels. Low position of left kidney
	L.R.	—	13(*l.r.*)	—	—	13	7 (2–8)		
	R.R.	—	13(*l.r.*)	—	—	13	7 (2–8)		
Gladstone and Wakeley	V.	7	13	5	5	—	—	F.	Synostosis of atlas with occipital bone. Asymmetry and irregularity of vertebrae
	L.R.	7th C.	12	—	—	13	—		
	R.R.	7th C.	12	—	—	13	—		
Gladstone and Wakeley 19 mm. human embryo	V.	7	11	6	5	—	—	F.	Excess of pericardial fluid and irregular formation of thoracic wall
	L.R.	7th C.	11	—	—	12	—		
	R.R.	7th C.	11	—	—	12	—		
Goodhart (1)	V.	6½	11½	5½	—	—	—	M.	Atlas and occipital bone fused. Axis and 3rd cervical vertebrae fused and 7th cervical vertebra fused with 1st dorsal vertebra. 1st and 3rd left costal cartilages did not reach sternum. Body of 1st left vertebra absent. Spinal curvature, defective development of left arm and hand
	L.R.	(1)	12	—	—	13	7		
	R.R.	—	12	—	—	12	8		
Goodhart (2) foetal skeleton	V.	5½	12	—	—	—	—	M.	Spina bifida. Scoliosis. Defective development of occipital bone. Hydrocephalus. Talipes of both feet. 2nd and 3rd dorsal vertebrae fused. Irregularity in form
	L.R.	—	11	—	—	11	—		
	R.R.	—	11	—	—	11	—		
Goodhart (3)	V.	—	—	—	—	—	—	—	Fusion and irregularity of dorsal vertebrae, with fusion of laminae and spine. Scoliosis
	L.R.	—	—	—	—	—	—		
	R.R.	—	—	—	—	—	—		

Table I (*continued*)

Author		C.	T.	L.	S.	Total no. of ribs	No. of sternal ribs	Sex	Deformations
Harris	V.	7	11½	5	5	—	—	M.	Costal element of right transverse process of atlas ligamentous. 2nd and 3rd cervical vertebrae fused. Vertebral artery passes through 7th transverse process. Tracheo-oesophageal fistula. Stenosis of oesophagus. Imperforate anus. Vascular and cardiac anomalies. Absence of left kidney
	L.R.	—	10	1st L.	—	11	7		
	R.R.	—	12	—	—	12	7		
Helm	V.	—	—	—	—	—	—	—	Asymmetry of sternum. Right subclavian artery anterior to anterior scalene muscle. Accessory phrenic nerve
	L.R.	—	12	—	—	12	7		
	R.R.	—	12(*l.r.*)	—	—	12	8		
Hertslet and Keith (A)	V.	7	11	6	5	—	—	F.	Vertebral arteries enter 5th cervical vertebra
	L.R.	7th C.	11	—	—	12	—		
	R.R.	7th C.	11	—	—	12	—		
Hertslet and Keith (B)	V.	7	12	—	—	—	—	M.	Sternoscapular muscle. Stylohyoid ligament ossified. Levator anguli scapulae inserted into 2nd rib as well as into scapula
	L.R.	—	12(*l.r.*)	—	—	12	—		
	R.R.	—	12(*l.r.*)	—	—	12	—		
Jones	V.	7	12	(5)	(5)	—	—	F.	Costal cartilages of 1st and 2nd rib joined at their sternal extremities
	L.R.	—	12(*l.r.*)	—	—	12	8		
	R.R.	—	12(*l.r.*)	—	—	12	8		
Lane	V.	8	12	5	—	—	—	—	25 pre-sacral vertebrae. Lane considered that an extra vertebra was intercalated in the cervical region. The 1st rib had the usual appearance of a cervical rib
	L.R.	8th C.	12	—	—	13	—		
	R.R.	8th C.	12	—	—	13	—		
Leboucq	V.	8	12	5	5	—	—	—	2nd and 3rd cervical vertebrae fused. Leboucq considered the 3rd cervical to be the intercalated vertebrae
	L.R.	8th C.	12	—	—	13	—		
	R.R.	8th C.	12	—	—	13	—		
Lucas (I)	V.	7	12	—	—	—	—	F.	
	L.R.	7th C.	12	—	—	13	—		
	R.R.	7th C.	12	—	—	13	—		
Lucas (II)	V.	7	11	5	6	—	—	M.	Prefixed lumbar plexus
	L.R.	7th C.	11	—	—	12	—		
	R.R.	7th C.	11	—	—	12	—		

Table I (*continued*)

Author		C.	T.	L.	S.	Total no. of ribs	No. of sternal ribs	Sex	Deformations
Macphail	V.	7	12	—	—	—	—	M.	Sternal end of left clavicle prolonged downward in a hook-shaped manner. Costal cartilages of 2nd ribs directed obliquely downward by the side of the manubrium. Muscular abnormalities
	L.R.	—	12(*l.r.*)	—	—	12	—		
	R.R.	—	12(*l.r.*)	—	—	12	—		
Morris	V.	7	—	—	—	—	—	—	Syringomyelia
	L.R.	7th C.	—	—	—	—	—		
	R.R.	7th C.	—	—	—	—	—		
Paterson and Lovegrove (I)	V.	7	12	6	4	—	—	—	Imperfect formation with irregularity in union of the neural arches in the cervical region. 6th and 7th left ribs fused near their vertebral ends
	L.R.	7th C.	12	—	—	13	—		
	R.R.	7th C.	12	1st L.	—	14	—		
Paterson and Lovegrove (II)	V.	7	13	6	5	—	—	—	Irregularity of neural arches in cervical region. Left half of 3rd and right half of 4th neural arches fused. Fusion of 6th and 7th left ribs
	L.R.	7th C.	12	—	—	13	—		
	R.R.	7th C.	13	—	—	14	—		
Phillips (I)	V.	7	12	5	5	—	—	M.	Spina bifida involving atlas and axis. 5th lumbar vertebra in two parts. Irregular union of costal cartilages with sternum. Manubrium 3 in. long
	L.R.	7th C.	12	—	—	13	7		
	R.R.	7th C.	12	—	—	13	8		
Phillips (II)	V.	7	12	5	5	—	—	F.	Irregularity of union of costal cartilages with sternum. 5th and 6th cervical vertebrae fused. Foramina in gladiolus and ensiform appendix
	L.R.	7th C.	12	—	—	13	7		
	R.R.	7th C.	12	—	—	13	7		
Railliet	V.	7	—	—	—	—	—	F.	Left side of face smaller than right. Enophthalmos. Left hemicrania. Teeth lost on left side. Mother nervous. Father alcoholic. Brother in an asylum. Asymmetry of face in an aunt. Right side of face atrophied in grandmother
	L.R.	7th C.	—	—	—	—	—		
	R.R.	7th C.	—	—	—	—	—		
Roederer	V.	7	—	—	—	—	—	—	Subluxation of left sternoclavicular joint. Scoliosis
	L.R.	7th C.	—	—	—	—	—		
	R.R.	7th C.	—	—	—	—	—		
Rosenberg	V.	7	13	6	—	—	—	—	
	L.R.	7th C.	13	1	—	15	—		
	R.R.	7th C.	13	1	—	15	—		

Table I (*continued*)

Author		C.	T.	L.	S.	Total no. of ribs	No. of sternal ribs	Sex	Deformations
Royal College of Surgeons of England 500. 3	V.	6½	12	5	—	—	—	—	Atlas ankylosed to occipital bone. Axis and 3rd cervical vertebrae fused. Left half of 7th cervical vertebra absent. In consequence 6th cervical vertebra has descended into contact with 1st dorsal vertebra and an angular curvature is present with concavity to left. The left transverse process of the 1st dorsal vertebra has assumed characteristics of the transverse process of a 7th cervical vertebra. 1st thoracic rib absent on left. Costal cartilages of 2nd and 3rd ribs inserted together into lateral angle of manubrium sterni in usual situation of 1st costal cartilage. The costal cartilage of the 4th rib joins sternum at junction of manubrium with body. Manubrium joined on right to 1st, 2nd and 3rd costal cartilages. 4th upper dorsal vertebra ankylosed. Lumbar vertebrae fused and irregular
	L.R.	—	11	1	—	12	2–8		
	R.R.	—	12	—	—	12	1–7		
Still	V.	7	12	5	5	—	—	F.	Costal cartilage of 4th and 5th ribs of left side join to form single broad cartilage attached to sternum. Arrested development of infundibular part of right ventricle of heart. Patent interventricular foramen and foramen ovale. Little fingers of both hands stunted. Mongoloid type. Blue baby
	L.R.	—	12	—	—	12	—		
	R.R.	—	11	—	—	11	—		
Struthers (I)	V.	7	4+	—	—	—	—	M.	Vertebral foramen on each side of 6th cervical vertebra completed by bar of bone which is independent of the neck of the rib. Vertebral foramen of transverse process of 7th cervical vertebra completed on left side by bar of bone, on right by ligament
	L.R.	6, 7	4+	—	—	? 14	—		
	R.R.	6, 7	4+	—	—	? 14	—		
Struthers (II)	V.	6, 7	2+	—	—	—	—	F.	Cervical ribs form entire anterior boundary of vertebral foramen
	L.R.	7th	2+	—	—	? 13	—		
	R.R.	7th	2+	—	—	? 13	—		
Struthers (III)	V.	7	12	5	5	—	—	—	The neck of each cervical rib bounds the transversarium foramen
	L.R.	7th	12	—	—	13	—		
	R.R.	7th	12	—	—	13	—		
Struthers (IV)	V.	7	1+	—	—	—	—	—	7th cervical rib of left side ankylosed to transverse process. Right cervical rib movable
	L.R.	7th	1+	—	—	? 13	—		
	R.R.	7th	1+	—	—	? 13	—		
Struthers (V)	V.	7	12	5	5	—	—	F.	7th cervical rib of left side free, ankylosed rib on right side. 12th thoracic ribs small. Atlas has posterior bridge on both sides
	L.R.	7th	12	—	—	13	—		
	R.R.	7th	12	—	—	13	—		

Table I (*continued*)

Author		C.	T.	L.	S.	Total no. of ribs	No. of sternal ribs	Sex	Deformations
Struthers (VI)	V.	7	—	—	—	—	—	—	Laminae of atlas ununited. Cervical rib on left side free, on right side ankylosed externally
	L.R.	7th	—	—	—	—	—		
	R.R.	7th	—	—	—	—	—		
Struthers (VII *a*)	V.	7	—	—	—	—	—	F.	7th cervical vertebra has, on right side, notch for head of thoracic rib
	L.R.	7th	—	—	—	—	—		
	R.R.	7th	—	—	—	—	—		
Struthers (VII *b*)	V.	7	—	—	—	—	—	F.	
	L.R.	7th	—	—	—	—	—		
	R.R.	7th	—	—	—	—	—		
Struthers (VIII)	V.	7	12	5	5	—	—	M.	Existence of cervical ribs inferred from the presence of facets for them on the body and transverse processes of the 7th cervical vertebra. Lateral foramen appears to be wanting
	L.R.	7th	12	—	—	13	—		
	R.R.	7th	12	—	—	13	—		
Struthers (IX)	V.	—	—	—	—	—	—	F.	Cervical rib resting by its anterior end on a cornual process of the 1st thoracic rib. Recognised during life and removed post-mortem
	L.R.	7th	1+	—	—	—	—		
	R.R.	?	—	—	—	—	—		
Struthers (X)	V.	7	12	5	5	—	—	F.	Right cervical rib joined to cornual process on 1st thoracic rib. Left cervical rib reaches sternum. Left vertebral artery entered foramen in 5th cervical vertebra
	L.R.	7th	12	—	—	13	? 8		
	R.R.	7th	12	—	—	13	? 7		
Struthers (XI)	V.	—	—	—	—	—	—	F.	No symptoms. Visible pulsation of left subclavian artery
	L.R.	7th	—	—	—	—	—		
	R.R.	—	—	—	—	—	—		
Struthers (XII)	V.	—	—	—	—	—	—	M.	Visible pulsations of right subclavian artery
	L.R.	—	—	—	—	—	—		
	R.R.	7th	—	—	—	—	—		
Struthers (XIII)	V.	7	12	5	5	—	—	M.	1st and 2nd thoracic ribs on each side articulate with upper part of manubrium by a common cartilage. Fibrous band from the 1st rib on each side joins the tip of a cornual process of 1st rib cartilage. Manubrium long. 3rd rib cartilages join sternum at junction of manubrium and gladiolus
	L.R.	—	12(*l.r.*)	—	—	12	8		
	R.R.	—	12(*l.r.*)	—	—	12	8		

Table I (*continued*)

Author		C.	T.	L.	S.	Total no. of ribs	No. of sternal ribs	Sex	Deformations
Terry	V.	(7)	(12)	(5)	(5)	—	—	F.	Scoliosis. Metopic suture. Divided parietals. Wormian bones. Rudimentary clavicles. Manubrium divided into right and left halves by vertical suture. Gladiolus consists of four separate units. Contracted pelvis. Separation of lower from upper part of sacrum
	L.R.	—	12	—	—	12	8		
	R.R.	—	12	—	—	12	8		
Todd (A)	V.	7	11	6	5	—	—	M.	Atlas shows an ossified bridge over vertebral artery. There is a double foramen transversarium in the 6th cervical vertebra
	L.R.	7th C.	11	—	—	12	—		
	R.R.	7th C.	11	—	—	12	—		
Todd (B)	V.	7	12	5	—	—	—	M.	6th cervical vertebra asymmetrical. 1st left thoracic rib has a tubercle for articulation with the cervical rib
	L.R.	7th C.	12	—	—	13	—		
	R.R.	7th C.	12	—	—	13	—		
Todd (C)	V.	7	5	—	—	—	—	M.	Scoliosis. "Pathological changes have taken place in bodies and articular processes of cervical region producing scoliosis"
	L.R.	—	5 (*l.r.*)	—	—	—	—		
	R.R.	—	5 (*l.r.*)	—	—	—	—		
Todd (D)	V.	7	12	5	5	—	—	F.	
	L.R.	—	12	—	—	12	7		
	R.R.	7th C.	12	—	—	13	7		
Turner (A)	V.	7	12	—	—	—	—	M.	
	L.R.	7th C.	12	—	—	13	—		
	R.R.	7th C.	12	—	—	13	—		
Turner (B)	V.	7	12	—	—	—	—	F.	The spine of this old woman was greatly curved—the ribs distorted and the pelvis contracted
	L.R.	7th C.	12	—	—	13	—		
	R.R.	7th C.	12	—	—	13	—		
Turner (C)	V.	7	12	—	—	—	—	M.	
	L.R.	—	12	—	—	12	—		
	R.R.	7th	12	—	—	13	—		
Turner (D)	V.	7	12	5	—	—	—	M.	1st thoracic rib of left side so fused with 2nd thoracic rib, that this appeared bicipital. Sternal end was present, as cartilage attached to lateral angle of the sternum in normal situation of costal cartilage of 1st thoracic rib. This was connected with the 2nd rib and tip of the 1st rib by a fibrous cord

of the sternum and various abnormalities of the soft parts, as well as the above-mentioned defects of the vertebral column. The more important of these defects appear to arise as a primary disturbance of segmentation which has taken place at an early stage of development, and involved in some cases the neural tube, and the spinal nerves arising from it (Brash). Others are secondary results of the primary disturbance in segmentation. They may be purely adaptive, and take place during the intra-uterine growth of the embryo, or in some cases, in infancy or adult life.

An example of the former is the extension upwards, in certain cases of rudimentary 1st thoracic rib, of the attachment of the cartilage of the 2nd thoracic rib on the side of the sternum, so as to stabilise the manubrium, and compensate for the loss of support which is normally given to its lateral angle by a fully developed 1st thoracic rib. The same result may be obtained by the bending upward of the 2nd thoracic rib, so that the cephalic border of its costal cartilage will become attached to the lateral edge of the manubrium, and the size of the thoracic inlet at the same time becoming diminished, will thus approximate to the normal proportion (case VIII, of authors).

Some of the secondary changes are obviously not adaptive, but the result of an interference of the nerve or vascular supply of a developing organ, e.g. in the case of suppression of one half of a vertebra with absence of the corresponding rib, and intercostal structures, including the somatic and splanchnic nerves. In such a case there may be loss of tone in the wall of the corresponding segment of the intestine, followed by an interruption of the peristaltic wave, and dilatation of the part beyond.

Table II. *Cervical ribs* (32 *cases*)

Author	M.	F.	Author	M.	F.
Addison	—	1	Struthers	1	—
Barclay-Smith	—	1	,,	—	1
Bateson	—	1	,,	—	1
,,	1	—	,,	1	—
Black	—	1	,,	—	1
Brash	1	—	,,	—	1
Dagnini	1	—	,,	—	1
Edington	1	—	,,	—	1
Gladstone and Wakeley	—	2	,,	1	—
Hertslet and Keith	—	1	Todd	1	—
Lucas	—	1	,,	1	—
,,	1	—	,,	—	1
Phillips	1	—	Turner	1	—
,,	—	1	,,	—	1
Railliet	—	1	,,	1	—
Struthers	—	1			

Total: M. 13, F. 19.

Table III. *Rudimentary 1st thoracic ribs* (9 *cases*)

Author	M.	F	Author	M.	F.
Dow	1	—	Macphail	1	—
Dwight	—	1	Struthers	1	—
Gladstone and Wakeley	1	—	Todd	1	—
Hertslet and Keith	1	—	Turner	1	—
Jones	—	1			

Total: M. 7, F. 2.

Table IV. *Cervical ribs and rudimentary 1st thoracic ribs* (41)

M.	F.
20	21

Table V. *Irregular formation and ankylosis of vertebrae associated with cervical ribs, rudimentary 1st thoracic ribs, or other variations in the number of ribs* (70)

Author	No. of cases	Author	No. of cases
Babcock	1	Lane	1
Barclay-Smith	1	Leboucq	2
Bateson	1	Paterson and Lovegrove	2
Brash	1	Phillips	2
De Vernejoul et Chauvin	1	R.C.S. Eng. 500. 3	1
Dukes and Owen	1	Struthers	1
Dwight	5	Terry	1
Edington	1	Todd	2
Gladstone and Wakeley	2	Turner	1
Goodhart	2	Wakeley	3
Harris	1		

Total no. of cases, 33. Percentage no. 47·14.

Table VI. *Congenital scoliosis of vertebral column, associated with congenital variations in the number of ribs* (70)

Author	No. of cases	Author	No. of cases
Babcock	1	Goodhart	2
Dagnini	1	Roederer	1
De Vernejoul et Chauvin	1	Todd	1
Dwight	1	Turner	1
Edington	1	Wakeley	3
Gladstone and Wakeley	2		

Total no. of cases, 15. Percentage no. 21·43.

Table VII. *Cases in which it was recorded that eight or nine ribs articulated with the sternum*

Author	Cervical rib	Rudimentary 1st thoracic rib
Edington	(2)	—
Helm	—	(1)
Jones	—	(2)
Phillips	(1)	—
Struthers	—	(2)
Total (5)	2 cases	3 cases

Table VIII. *Cases in which it was recorded that seven ribs, from 2nd to 8th, articulated with the sternum*

Author	Cervical rib	Rudimentary 1st thoracic rib
Gladstone and Wakeley	—	(2)
Royal College of Surgeons	—	(1)
Total (2)	—	2

The numeral (1) indicates that the condition is unilateral, (2) that the condition is bilateral.

According to these tables it appears that 7th cervical ribs are more commonly present than rudimentary 1st thoracic ribs, that cervical ribs are more commonly present in the female than in the male, and a rudimentary condition of the 1st thoracic rib is relatively more common in the male sex. This accords with the general opinion based on clinical observations but the number

Table IX. *Cases of cervical ribs in which the total number of ribs and their relation to the vertebral column has been recorded*

	Total no. of left ribs					Total no. of right ribs					
Author	11	12	13	14	15	11	12	13	14	15	
Addison	.	.	+1	.	.	.	.	+1	.	.	Bilateral
Babcock	.	1	.	.	.	.	.	+1	.	.	Unilateral
Barclay Smith	.	1	.	.	.	.	.	+1	.	.	,,
Bateson	.	1	.	.	.	.	1	.	.	.	Bilateral
,,	.	1	.	.	.	.	1	.	.	.	,,
Black	.	.	+1	.	.	.	.	+1	.	.	,,
Dagnini	.	.	+1	.	.	.	.	+1	.	.	,,
De Vernejoul et Chauvin	.	.	+1	.	.	.	1	.	.	.	Unilateral
Dwight	.	1	.	.	.	.	1	.	.	.	Bilateral
,,	.	1	.	.	.	.	1	.	.	.	,,
Edington	.	.	.	+ +1	.	1	.	.	.	.	,,
Gaucher et Crouzon	.	.	+1	.	.	.	1	.	.	.	Unilateral
Gladstone and Wakeley	.	.	+1	.	.	.	.	+1	.	.	Bilateral
,, ,,	.	1	.	.	.	.	1	.	.	.	,,
Goodhart	.	.	+1	.	.	.	1	.	.	.	Unilateral
Hertslet and Keith	.	1	.	.	.	.	1	.	.	.	Bilateral
Lane	.	.	+1	.	.	.	.	+1	.	.	,,
Leboucq	.	.	+1	.	.	.	.	+1	.	.	,,
,,	.	.	+1	.	.	.	.	+1	.	.	,,
Lucas	.	.	+1	.	.	.	.	+1	.	.	,,
,,	.	1	.	.	.	.	1	.	.	.	,,
Paterson and Lovegrove	.	.	+1	.	.	.	.	+1	.	.	,,
Phillips	.	.	+1	.	.	.	.	+1	.	.	,,
,,	.	.	+1	.	.	.	.	+1	.	.	,,
Rosenberg	.	.	.	.	+1+ +	.	.	.	.	+1+ +	,,
Struthers (III)	.	.	+1	.	.	.	.	+1	.	.	,,
,, (V)	.	.	+1	.	.	.	.	+1	.	.	,,
,, (VIII)	.	.	+1	.	.	.	.	+1	.	.	,,
,, (X)	.	.	+1	.	.	.	.	+1	.	.	,,
Todd	.	1	.	.	.	.	1	.	.	.	,,
,,	.	.	+1	.	.	.	.	+1	.	.	,,
,,	.	1	.	.	.	.	.	+1	.	.	Unilateral
Turner	.	.	+1	.	.	.	.	+1	.	.	Bilateral
,,	.	.	+1	.	.	.	.	+1	.	.	,,
,,	.	1	.	.	.	.	.	+1	.	.	Unilateral
	.	12	21	1	1	1	11	22	—	1	Bilateral 28
											Unilateral 7

The + mark placed on the left side of the figure in a column indicates that the additional rib or ribs were considered to be cervical. The + mark on the right side of the figure indicates the presence of lumbar ribs. The table shows that there is an increase in the total number of ribs in cases of cervical ribs in approximately $\frac{2}{3}$ of the total number of cases.

of cases recorded is obviously too small to make a final statement with regard to sex frequency. It will be observed, however, Table IV, that when the figures relating to sex frequency in the two types of cases (cervical ribs, and rudimentary 1st thoracic ribs) are combined, the ratios are almost equal.

Records of observations on the exact relations of the ventral ends of the ribs to the sternum in cases of rudimentary 1st thoracic ribs and 7th cervical ribs

are unfortunately too few for any statistical statement to be of much value. We consider however that more attention should be paid to this relation than has been the case hitherto. Clinically it is of importance to distinguish the two conditions one from the other. From the morphological standpoint the very occasional presence of a triangular plate of cartilage attached to the lateral angle of the manubrium sterni in cases of incomplete 7th cervical rib offers a morphological problem which is of considerable interest in connection with the developmental relation of the ventral ends of the ribs to the sternum. This question we propose to consider fully in a subsequent contribution dealing with the origin and development of the sternum.

Table X. *Cases of rudimentary 1st thoracic ribs in which the total number of ribs and their relation to the vertebral column has been recorded*

	Total no. of left ribs					Total no. of right ribs					
Author	11	12	13	14	15	11	12	13	14	15	
Bellamy	.	−1	.	.	.	.	−1	.	.	.	Bilateral
Dow	.	−1	.	.	.	.	−1	.	.	.	„
„	.	−1	.	.	.	.	−1	.	.	.	„
Dukes and Owen	.	−1	.	.	.	.	−1	.	.	.	„
Dwight	.	−1	.	.	.	.	−1	.	.	.	„
Gladstone and Wakeley	.	.	−1	.	.	.	.	−1	.	.	„
Helm	.	+1	.	.	.	.	−1	.	.	.	Unilateral
Hertslet and Keith	.	−1	.	.	.	.	−1	.	.	.	Bilateral
Jones	.	−1	.	.	.	.	−1	.	.	.	„
Macphail	.	−1	.	.	.	.	−1	.	.	.	„
Struthers	.	−1	.	.	.	.	−1	.	.	.	„
Turner	.	−1	.	.	.	.	+1	.	.	.	Unilateral
Total	.	−10	−1	.	.	.	−10	−1	.	.	Bilateral 10 Unilateral 2

The − mark placed to the left of a figure indicates a rudimentary condition of the 1st thoracic rib on the side indicated. If a + sign is present the 1st thoracic rib is complete on that side. The table shows that lumbar ribs are only occasionally present in cases of rudimentary 1st thoracic ribs.

Table XI. *Cases in which thirteen pairs of ribs have been present, the additional ribs having been recorded as 8th cervical: in which also an additional pre-sacral vertebra was present, and was regarded as an intercalated cervical vertebral*

Author	Ribs		
Lane	8th cervical	12 T.	Bilateral
Leboucq	„	12 T.	„
„	„	12 T.	„

SUMMARY OF CLINICAL OBSERVATIONS AND RESULTS OF TREATMENT

The symptoms caused by cervical ribs are those due to pressure upon the subclavian artery and brachial nerve trunks. As a rule the shorter ribs are more prone to cause pressure on the brachial plexus, and the longer ones to cause compression of the subclavian artery. The rib can be exposed by an incision along the posterior border of the sterno-mastoid muscle and if a bigger exposure is necessary, the incision may be prolonged outwards along the upper

border of the inner third of the clavicle. The scalenus anticus muscle is exposed and divided at its insertion. This procedure itself may be all that is required; however, if there is still some pressure on the artery or nerves, the anterior part of the rib is excised subperiosteally; by so doing no important structures are injured.

The results of operations for relief of symptoms in cases of cervical ribs are not uniformly good, especially where the brachial plexus has been pressed upon. This is due to the fact that the pressure on the nerves has been of long standing and only partial recovery can be anticipated.

In some cases an enlarged and elevated 1st thoracic rib may of itself produce symptoms similar to those of a cervical rib, especially if it is situated

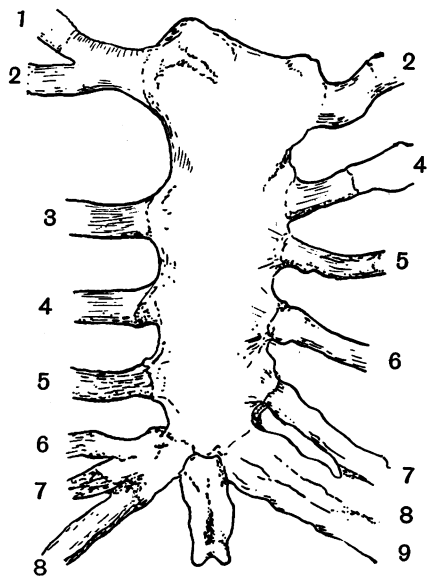

Fig. 15. Sternum and costal cartilages of a skeleton in which there was great irregularity, associated with defective development and fusion of the vertebrae and ribs. The 1st and 3rd ribs of the left side failed to reach the sternum. The specimen illustrates the apparently fortuitous manner in which the ribs may join the sternum under these conditions.

nearer the brachial plexus than usual. In these cases, removal of the middle third of the rib subperiosteally, will generally free the patient from all symptoms.

The study of the relation of abnormal ribs to the sternum (see fig. 15) is one which involves the study of the normal relations of the developing ribs and sternum to each other, not only in Man, but in all classes of vertebrate animals. At the present time, the opinions of morphologists and various workers who have been studying the ontogeny of the sternum differ in a most fundamental manner. We have, therefore, devoted a considerable amount of time and attention to the study of the chief points at issue from the palaeontological,

comparative and ontogenetic aspects, in the hope of coming to a final conclusion as to the extent to which the shoulder girdle, ribs, and somatic mesoderm are concerned in the development of the sternum in Man, and representative types of various vertebrate animals.

A part of this work has already been communicated to the Anatomical Society at the last meeting, held at King's College, London, in June 1931. At this meeting, slides were shown illustrating the history of its development as indicated by the ventral median cartilages of certain Fishes; various types of sternal apparatus in Amphibia, and Reptiles, including the bilateral elliptical bony plates found in certain extinct Reptiles; and also representative forms of sternum in Birds and Mammals. Models of the developing sternum of a mouse and of a rabbit embryo illustrating the relation of the ribs to the sternum in the *prochondral* and early *chondral* stages were also shown, and the development of the sternum in these rodents described.

A general description of the ontogeny of the sternum and the varying relations of the ribs to the sternum in Man and different types of vertebrate animals is obviously too extensive a subject to be dealt with in this paper. The authors have, therefore, decided to postpone the discussion of this matter and its relation to abnormalities of the ribs for a communication which will be published as a sequel to the present paper.

REFERENCES

ADDISON, C. (1902). "Cervical ribs." *Proc. Anat. Soc., J. Anat. and Physiol.* vol. XXXVI.

BABCOCK, W. W. (1905). "Cervical rib, with resulting gangrene of fingers." *Amer. Med. J.* vol. XVI, p. 6161.

BARCLAY-SMITH, E. (1911). "Multiple anomaly in a vertebral column." *J. Anat.* vol. XLV, p. 144.

BATESON, W. (1894). *Materials for the Study of Variation.* Meristic variation of vertebrae and ribs, pp. 102–44. Macmillan and Co.

BASSOE, P. (1920). "Coincidence of cervical ribs and syringo-myelia." *Arch. Neur. Psych.* vol. IV, p. 542.

BELLAMY, E. (1874–5). "On a spine possessing a sixth lumbar vertebra, the first ribs being rudimentary." *J. Anat. and Physiol.* vol. IX, p. 185.

BENIANS, T. H. C. and JONES, H. E. (1910). "Congenital deficiency of a portion of the thoracic skeleton." *J. Anat. and Physiol.* vol. XLIV, p. 67.

BLACK, J. (1898). "Report of a case of cervical ribs." *Proc. Anat. Soc. Gt Brit. and Ireland,* vol. XLVII.

BRADLEY, O. C. (1902). "Case of rudimentary first thoracic rib in a horse." *J. Anat. and Physiol.* vol. XXXVI, p. 54.

BRASH, J. C. (1915). "An anomalous vertebral column." *J. Anat. and Physiol.* vol. XLIX, p. 243.

CAVE, A. J. E. (1930). "On fusion of the atlas and axis vertebrae." *J. Anat.* vol. LXIV, p. 337.

CLELAND, J. (1882–3). "Contribution to the study of Spina Bifida, Encephalocele and Anencephalus." *J. Anat. and Physiol.* vol. XVII, p. 257.

CROUZON, A. *vide* GAUCHER, E.

DAGNINI, G. (1922). *Policlinio, Roma,* vol. XXIX, p. 109.

DOW, D. RUTHERFORD (1925). "The anatomy of rudimentary first thoracic ribs, with special reference to the arrangement of the brachial plexus." *J. Anat.* vol. LIX, p. 166.

DUCKWORTH, W. L. H. (1911). "Report on an abnormal first thoracic vertebra." *J. Anat. and Physiol.* vol. XLV, p. 65.

DUKES, L. and OWEN, S. A. (1902). "Anomalies in the cervical and upper thoracic regions, involving cervical vertebrae, first rib and brachial plexus." *J. Anat. and Physiol.* vol. XXXVI, p. 290.

DWIGHT, T. (1901). "Description of human spines showing numerical variation." *Anat. Anz.* vol. XIX, pp. 321–32, 337–47.

—— (1911). "Irregular ossifications in the space between the transverse process and the rib at the junction of the neck and thorax." *J. Anat. and Physiol.* vol. XLV, p. 438.

EDINGTON, G. H. (1904). "Multiple malformations (genito-urinary and skeletal) occurring on one side of the body in a case of atresia ani." *J. Anat. and Physiol.* vol. XXXVIII, p. 476.

GAUCHER, E. et CROUZON, A. (1913). "Une observation de côtes cervicales d'origine hérédo-syphilitique." *Bull. et Mém. Soc. méd. d. hôp. de Paris*, t. XXXVI, p. 98.

GLADSTONE, R. J. and WAKELEY, C. P. G. (1913). "Defective development of the mandibular arch. The etiology of arrested development, and an enquiry into the question of the inheritance of congenital defects." *J. Anat.* vol. LVII, p. 149.

GLADSTONE, R. J. (1912). "A case of left inferior vena cava, in which the twelfth ribs were absent." *J. Anat. and Physiol.* vol. XLVI, p. 220.

GLADSTONE, R. J. and ERICHSEN-POWELL, W. (1915). "Manifestation of occipital vertebrae and fusion of the atlas with the occipital bone." *J. Anat. and Physiol.* vol. XLIX, p. 190.

GOODHART, J. F. (1875). "Description of three cases of malformation of the spinal column associated with lateral curvature." *J. Anat. and Physiol.* vol. IX, p. 1.

GORTON, B. (1923). "Abnormal seventh cervical vertebra of a horse." *J. Anat.* vol. LVII, p. 380.

HARRIS, H. A. (1923). "A foetus presenting a combination of rare anomalies." *J. Anat.* vol. LVII, p. 76.

HARROWER, G. (1923). "Variations in the region of the cranio-vertebral boundary." *J. Anat.* vol. LVII, p. 178.

HELM, F. (1895). "Einseitige rudimentare Entwickelung der ersten Rippe nebst einer Anzahl anderer Anomalien am Thorax einer und derselben Person." *Anat. Anz.* Bd. X, S. 540–54.

HERTSLET, L. E. and KEITH, A. (1896). "A comparison of the anomalous parts of two subjects, the one with a cervical rib, the other with a rudimentary first rib." *J. Anat. and Physiol.* vol. XXX.

HONEIJ, J. A. (1920). "Cervical ribs." *Surg. Gynec. Obstet.* vol. XXX, p. 481.

JONES, F. W. (1911). "Variations of the first rib." *J. Anat. and Physiol.* vol. XLV, p. 249.

—— (1910). "On the relation of the limb plexuses to the ribs and vertebral column." *J. Anat. and Physiol.* vol. XLIV, p. 377.

KEENE, M. F. L. and HEWER, E. E. (1927). "The development of the human suprarenal gland." *J. Anat.* vol. LXI, p. 302.

LANE, W. A. (1885). "Supernumerary cervico-dorsal vertebra bearing ribs, with vertebral and costal asymmetry." *J. Anat. and Physiol.* vol. XIX, p. 266.

LEBOUCQ, H. (1898). "Recherches sur les variations anatomiques de la première côte chez l'homme." *Archives de Biologie*, t. XV.

LUCAS, M. F. (1915). "Two cases of cervical ribs." *J. Anat.* vol. XLIX, p. 336.

MACPHAIL, A. (1902). "Rudimentary first dorsal ribs." *Proc. Anat. Soc., J. Anat. and Physiol.* vol. XXXVI, p. 70.

MORRIS, C. H. (1922). "Syringomyelia associated with cervical ribs." *J. Amer. Med. Ass.* vol. LXXVIII, p. 109.

MOUCHET, A. (1910). "Sur la Gouttière artérielle de la première côte." *Anat. Anz.* Bd. XXXVI, S. 591.

OSBURN, R. C. (1907). *Amer. J. Anat.* vol. VII, p. 171.

PATERSON, A. M. and LOVEGROVE (1898). "Peculiarities of the foetal vertebral column." *Proc. Anat. Soc. Gt Brit. and Ireland*, vol. III.

POPOWSKY, J. (1918). "Bifurcated extremities of ribs." *Anat. Anz.* Bd. XV, S. 284.

PRIMROSE, W. B. (1921). "Evolution of the vertebrate endoskeleton." *J. Anat.* vol. LV, p. 119.

REYNOLDS, S. H. (1897). *The vertebrate skeleton.* Camb. Univ. Press.

ROBB, G. D. (1922). "The clinical significance of cervical ribs." *New Zealand Med. J.* vol. XXI, p. 338.

ROEDERER, M. (1922). "Une observation de côte cervicale chez une scoliotique." *Bull. Soc. de pédiatr.* t. XX, p. 203.

SMITH, E. G. (1908). "Significance of fusion of atlas and occipital bone, and the manifestation of occipital vertebrae." *Brit. Med. J.* vol. II, p. 594.

STRUTHERS, J. (1874). "On variation of ribs and vertebrae in man." *J. Anat. and Physiol.* vol. IX, p. 46.

SWJETSCHNIKOW, V. (1906). "Ueber die Assimilation des Atlas und die Manifestation des Occipitalwirbels beim Menschen." *Archiv f. Anat. u. Phys., Anat. Abth.* S. 155–92.

TERRY, R. J. (1899). "Rudimentary clavicles and other abnormalities of the skeleton." *J. Anat. and Physiol.* vol. XXXIII.

TODD, T. WINGATE (1912). "Cervical rib: factors controlling its presence and its size. Its bearing on the morphology and development of the shoulder." *J. Anat. and Physiol.* vol. XLVI, p. 244.

—— (1911). "Relations of the thoracic operculum." *J. Anat. and Physiol.* vol. XLV, p. 293.

—— (1924). "Stability." *Scientific Monthly*, vol. IX, p. 632.

TREDGOLD, A. F. (1897). "Variations of ribs in the Primates with especial reference to the number of sternal ribs in Man." *J. Anat. and Physiol.* vol. XXXI, p. 288.

TURNER, W. (1883). "Cervical ribs and the so-called bicipital ribs in Man." *J. Anat. and Physiol.* vol. XVII, p. 382.

DE VERNEJOUL et CHAUVIN (1922). "Septième côte cervicale gauche avec scoliose cervico-dorsale." *Marseille Méd.* t. LIX, p. 1033.

WAKELEY, CECIL P. G. (1923). "A case of congenital scoliosis due to the suppression of half a vertebra." *J. Anat.* vol. LVII, p. 147.

—— (1930). *Trans. Med. Soc. Lond.* vol. LIII, p. 77.

—— (1930). *Proc. Roy. Soc. Med.* vol. XXIII, p. 995.