ON VARIATIONS OF THE VERTEBRAE AND RIBS IN MAN.

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Having over a number of years collected a considerable series of specimens illustrating variation of the vertebrae and ribs, I have thought that an account of them might prove interesting as a contribution to the facts of variation. Much that may appear to be mere detail will, I trust, not prove to be so to those who are engaged in the objective study of variation of these parts. It is, in truth, only after a close and critical examination that the nature and worth of a variation can be appreciated. Besides what else may appear, it will be evident from the following study, that individual variations of these parts are so frequent and may be so great, that conclusions as to characters of species, or differences of race, in order to be reliable must be founded on the examination of a series of specimens. The specimens are, I believe, all European, mostly obtained from my own dissecting rooms.

(A) Variations in the Cervical Region.

(a) Deficient ossification of the Atlas; anterior arch, posterior arch, transverse processes.

(b) Bridges of bone developed on the Atlas, over the nerve and artery. 14 cases.

(c) Consolidation of the Atlas and Occipital bone.

(d) Case in which the Muscles of the spine of the Axis are transferred to epispinous bones at the 3rd vertebra.

(e) Variation in the place of entry of the Vertebral Artery in the cervical vertebrae. 2 cases of artery entering foramen of the 7th, and 3 special cases.

(f) Additional foramen in the cervical transverse processes. Examination of numerous cases.

(g) Variation of 7th vertebra; lateral foramen, transverse processes, costal facets.

(h) Cervical Ribs. Examination of 10 cases illustrating the various degrees of development.

(i) Recognition of Cervical Ribs in the living body. 3 cases.

(B) Variations in the Thoracic Region.

(a) Imperfect development of 1st thoracic ribs. Case with remarks. Case in a three-toed Sloth.

(b) Varieties of the Sternal Ends of the ribs. 5 cases.

(c) Variation of the Costal Facets of the 9th and 10th dorsal vertebrae.

(d) Imperfect development of the 12th rib. 5 cases.

(e) Variation in the place at which change of the Articular Processes occurs. 10 cases. Note respecting position of this change in animals.

(C) Variations in the Lumbar Region.

(a) Cases 1 and 2, Lumbar Rib simply. Note of 2 cases in the Ox, differently placed.

(b) More complex lumbar variations; Vertebrae and Ribs.
Case 3. Dorso-lumbar vertebra more than usual, with additional pair of ribs. Note of another case of the same in Man, and of case of the same in a Cat.
4. Case of the same, with 6th lumbar vertebra partly sacralised.
5, 6 and 7. Three cases of 6 lumbar vertebrae.
8. Dorso-lumbar vertebra less than usual; 11 pairs of ribs, and 12th rib, or movable transverse process, on one side.
9. Case of 6 cervical vertebrae, and 6 lumbar vertebrae; and a vertebra suppressed in some part of the column.

(c) Variation of the 5th lumbar vertebra.
(1) Changes by which it becomes united to the sacrum. 4 cases. Note on this change in the Gorilla.
(2) Variations of its lower Articular Processes. Cases and remarks.
(3) Variations of the upper articular processes of the sacrum.

(D) Variations of the Sacrum.

(a) Diminution in the number of its component vertebrae.

(b) Variation in form of the upper sacral vertebra, apparently from borrowed lumbar vertebra. The Ape-like sacrum. 4 cases.

(c) Examination of 6 sacra, in which the upper vertebra is of unusual form, but in which the additional vertebra appears to have been obtained from the coccyx.

(d) Examination of 7 other cases in which a 6th vertebra is obtained from the coccyx.

(e) Variation in the number of sacral vertebrae with which the Ilium articulates.

(f) Variation in the form of the Auricular Surface.

(g) Case of Sacral Canal open in its whole length.

(E) Variations of the Coccyx.

(a) Diminution in the number of its component vertebrae. Cases of, and their nature.

(b) Increase. Remarks. Two cases of 10 sacro-coccygeal vertebrae.

(c) Union of the coccygeal vertebrae. External influences.

(A) Variations in the Cervical Region.

(a) Deficient ossification of the Atlas. Case 1. *Anterior arch mostly ligamentous, and containing a separate ossification.* This preparation is from a female subject aged 91. The gap in the bone is $\frac{3}{4}$ inch at the upper margin, $1\frac{1}{8}$ inch at the lower margin. It is occupied by a ligament flattened like the normal bony arch but not so deep. A scale of bone, $\frac{3}{8}$ inch in length, $\frac{1}{6}$ inch in height, lies in the right half of the ligament, having a distinct interval of ligament on its right side also. The edges of the gap are formed by two pointed processes which project for $\frac{1}{4}$ to $\frac{1}{3}$ inch inwards beyond the articular cavities. The fore ends of these cavities converge less than usual, being nearly as wide apart as the hinder ends are at their inner edge. The posterior arch, and the other parts of the bone, are well ossified and healthy looking. The odontoid process presents a raised platform against which especially the scale of bone has played.

Case 2. *One half of posterior arch of Atlas represented by a ligament.* An adult male subject. The rest of the cervical vertebrae well ossified and robust. The left side of the arch is well ossified, ending abruptly a little to the left of the middle line, where it attaches the ligament. The entire right half arch is ligamentous, including the part which represents the pedicle. The anterior transverse process of the same side is slender, tapering outwards, and is then ligamentous opposite the outer part of the foramen.

Case 3. *Mesial deficiency of posterior bony arch of Atlas.* The bone is otherwise robustly developed. The gap is about

¼ inch, the left arch ending abruptly, the right obliquely on its upper edge. Both half arches are well ossified, and the additional small foramen is present on both sides, about the size of a crow-quill, but oval. In the case of cervical rib No. 6, adult and the vertebrae robust, the two half arches of the atlas are just meeting by irregular ends, but are not united.

Deficiency of one of the transverse processes of the Atlas. In all the adult specimens of this deficiency before me, it is of the anterior process. In a female subject (case No. 1, lumbar variation) it is deficient externally on both sides. In a female skeleton, it is deficient on the right side in its outer half. In a male, aged 31, the neck otherwise well ossified, the outer half is deficient on the right side. In another case (case No. 4, cervical rib) the deficiency is of the outer part on the left side. At the same time it may be remarked that, in several of the specimens before me in which there is decided inequality of the two processes, the slender one is the posterior. This is partly owing to the posterior being more slender than usual, partly to the anterior process being unusually robust.

(b) OCCASIONAL BRIDGES OF BONE ON THE ATLAS OVER THE GROOVE FOR THE NERVE AND ARTERY. Two of these bony arches may occur, the nature of which may be readily understood by referring to the conditions presented by the more tube-like atlas of quadrupeds, and to the position of the sub-occipital nerve and vertebral artery, and the fibrous bands, in man. The *posterior bridge* is common and well known. It is represented normally by a strong fibrous arch. It curves from the back of the condyloid cup downwards and backwards to join the hinder edge of the arch, at a point where the two stages of the arch representing the pedicle and the lamina meet, thus converting the superior notch of the atlas into a foramen. I may note briefly the conditions in thirteen specimens of this variety before me, five of these being in cases to be referred to afterwards for other varieties.

1. Robust atlas; bridge on both sides; broad, being ⅛ inch in breadth at the middle.

2. Robust atlas; bridge on both sides; narrow, especially on right side.

3. Small atlas; bridge on both sides; about $\frac{1}{8}$ inch broad.

4. Female, aged 40 (case of cervical rib No. 5); bridge on both sides; an oval aperture in each arch near outer edge.

5. Male, aged 47 (case No. 4 of imperfectly developed 12th rib); on left side $\frac{1}{4}$ inch broad, with oval aperture in it $\frac{1}{6}$ inch long. On right side, incomplete at middle.

6. Male. Complete but narrow on left side. On right side, only a spur-like process hanging down from condyle.

7. Male. On right side, $\frac{1}{8}$ inch broad. Left side of atlas removed.

8. Robust atlas. On right side, complete and narrow. Left side a pointed process from above, very little from below.

9. (Case of cervical rib No. 4.) On right side complete, $\frac{1}{10}$ inch broad. Left side a pointed process from above, very little from below.

10. Robust spinal column. (Case No. 8, lumbar variation.) On right side two pointed processes nearly meeting at the middle. Left side the processes short and of about equal length.

11, 12, and 13. Three specimens (one of them case of cervical rib No. 6). Represented on both sides by an overhanging spur from the condyle and a slight ledge on the arch.

The *lateral bridge* is seen in the first of the above 13 cases. It passes from the outer edge of the condyloid cup, outwards and downwards to join the back part of the transverse process external to the foramen. Above, it is nearly half an inch in breadth, narrowing downwards to about $\frac{1}{8}$ inch. This is on the left side. On the right side, it appears to have had exactly the same arrangement but is broken. In the eighth of the above 13 specimens, the lateral bridge is about half formed on both sides, mainly from above. In another atlas it is fully half formed; on the left side, by a broad ledge projecting from above, and by a shorter pointed process from below, while on the right side it does not exist; nor on either side is there any part of a posterior bridge. While the posterior bridge adds one foramen to the atlas, a transverse one, the lateral bridge, arching over the vertebral artery as it ascends from

the lateral foramen, gives the appearance of other two foramina, antero-posterior in direction[1].

(c) CASE OF CONSOLIDATION OF THE ATLAS AND OCCIPITAL BONE. The first impression on seeing this specimen is that the condition is the result of former disease, but Professor Henle shewed me some years ago, in the Anatomical Museum of Göttingen, several specimens of the same condition, and he did not consider it as of pathological origin. There is no history to this case. It occurs in a prepared set of bones of the head. It is adult, as the basilar process had been united to the sphenoid; but not old, as the bones have all separated well at the sutures; and, from the appearance of the frontal bones and the jaws, is probably from a female.

The ankylosis is not merely articular, but fills up the anterior and posterior spaces, making the consolidation continuous; and, although there are vascular foramina here and there, there is no irregularity or excrescence, but a general appearance of healthiness. There is also shortening longitudinally, as if the occipital condyles had not been developed; the transverse processes of the atlas being $\frac{1}{8}$ to $\frac{1}{4}$ inch, instead of $\frac{1}{3}$ to $\frac{1}{2}$ inch, from the parts of the occipital bone above them, and the measurement taken from the lower edge of the anterior condyloid foramen to the centre of the inferior articular surface of the atlas being 8 to 9 lines instead of about 12 lines. No trace remains of the line of union of the articular surface. The tubercle and form of the anterior arch of the atlas are visible, but the bony continuity between them and the basilar process is not much thinner than the arch itself. It is pierced close to the left of the middle line by a vascular foramen which would admit a thick pin. The union of the posterior arch to the occipital bone is by a thinner plate of bone, in which, to the right side of the middle line, there is an irregular gap, left unossified, 3 lines across and 1 line in height. The posterior arch itself is much thinner than usual and without any rudi-

[1] Were the fibrous membrane which here covers over the vertebral artery between these two bridges also ossified, except the perforation in it which transmits the posterior division of the nerve, we should then have the condition of parts presented by the atlas of a baboon (cynocephalus porcarius) now before me, marking off a more definite posterior foramen.

mentary spine. The lateral foramen of the atlas is, on the left side, wide, embracing a full-sized round part internally and an irregular part externally, the two transverse processes meeting externally only by a narrow bar; on the right side they do not meet from deficiency of the anterior process. The foramen for the sub-occipital nerve and the vertebral artery is situated just behind the condyle, is rounded and scarcely so large as an average foramen for the vertebral artery. From the outlet of the anterior condyloid foramen, on both sides, a well-marked groove leads backwards to above the lateral foramen. It is smooth and sharp-edged, deep enough to form half a canal, wide enough to contain an under-sized vertebral artery, and appears as if it had transmitted something from the anterior condyloid foramen, but that foramen itself is below the average in size and scarcely so large as the groove would be if completed into a canal. Some occipital bones shew an irregular groove running backwards from the outlet of the anterior condyloid foramen. The articular surfaces for the axis are very fully developed, the facet for the front of the odontoid $6\frac{1}{2}$ lines across by 5 in height, and the inferior articulating surfaces of the atlas are above the average in size.

(d) CASE IN WHICH THE MUSCLES OF THE SPINE OF THE AXIS ARE TRANSFERRED TO EPISPINOUS BONES AT THE SPINE OF THE 3RD VERTEBRA. The spine of the axis wants its usual great size and is not bifurcated. Recti minores muscles normal. Interspinales absent as usual between atlas and axis, but present between axis and 3rd. The recti majores arise entirely at the spine of the 3rd vertebra. The inferior oblique also arises at the spine of the 3rd, but an additional portion, equal to $\frac{1}{4}$ the size of the lower, arises from the axis, deeper than the spine, and passes to join the greater portion above its middle. Superior oblique normal. At first the muscles attached at the spine of the 3rd vertebra seemed as if directly attached to a massive spinous process, but on dissection it was seen that they are attached to a pair of movable ossicles.

These epispinous bones are oval and flat, like small-sized almonds; length 6 to 7 lines, breadth 3 to 4 lines, thickness 1 line; the left being somewhat larger in all directions than

the right. They are attached to the corresponding tubercle of the spine of the 3rd vertebra, each by a strong, short, deep, ligament, and to each other by transverse ligamentous fibres passing between their inner margins. On dividing the latter, the ossicles can be moved outwards to $\frac{3}{4}$ inch from each other, and can be moved freely in all directions. The deep ligament is attached to the inner part of their deep surface, the muscles above mentioned to their upper end and outer surface. The spine of the 3rd vertebra is more developed than usual, the left tubercle being the larger. The interspinales in the space between the axis and 3rd vertebra are large and in two strata; the superficial, flattened laterally, diverge downwards and are attached to the deep surface of the epispinous ossicles and to the deep ligament; the deeper pair are parallel and more like ordinary inter-transversales. The fibres of the two sets blend at their attachment to the spine of the axis. The muscles which normally pass from below to the spine of the axis, were attached to the lower part of the epispinous ossicles.

When the ossicles are approximated, as they lay naturally, they form an elongated saddle-like covering to the 3rd spine, and can be moved freely (to the extent of half an inch) upwards and downwards, the deep ligaments then checking. In life, the preliminary action of the muscles from below would be required before the rectus major and inferior oblique could have a fixed point from which to act. It would appear that these ossicles represent the tubercles of the spine of the axis, developed separately and carried down to the spine of the vertebra below, carrying all the muscles with them, except those deeper fibres of the inferior oblique which may be seen to arise from the lamina rather than from the spinous process proper. In other respects the cervical vertebrae are normal, except that the 7th has carried its ribs longer than usual before they became ankylosed, especially on the right side.

(e) VARIATION IN THE PLACE OF ENTRY OF THE VERTEBRAL ARTERY IN THE CERVICAL VERTEBRAE. I may note under this head, as worthy of mention, two cases in which the vertebral artery entered the foramen of the 7th vertebra, and

three special cases of the artery, as not unfrequently occurs, entering higher than the 6th vertebra.

Case 1. *Left vertebral artery entering at the seventh vertebra.* Aged male subject. Artery arose nearly an inch earlier than usual from the subclavian, and entered the foramen in the transverse process of the 7th cervical vertebra. On right side, artery arose normally and entered at foramen of 6th vertebra. The bones have not been preserved.

Case 2. *Right vertebral artery arising last from the arch of the aorta, and entering at the seventh cervical vertebra.* Male subject, aged about 15 years. The right vertebral arose from the back of the aorta half an inch after the origin of the left subclavian. It passed obliquely up and across between the gullet and the first dorsal vertebra, and entered the foramen in the transverse process of the seventh cervical vertebra on the right side. The artery was of the normal size. This case occurred in 1854, and I cannot say more of the other arteries than that it is entered in my note-book at the time that they were normal. The macerated vertebrae are in my collection. On the right side, the foramen is large and rounded, not far from twice the capacity of the foramen of the vertebrae above it. Its anterior boundary is formed by a completely ankylosed rather narrow bar, bulged forwards, and without a tubercle. On the left side, the foramen is less than half the size of the right, and smaller than that of the vertebra above it. The cervical rib forming this boundary is not fully ankylosed, either at its inner or outer end; nor is the ossification of the 6th transverse process of this, the left, side completed, a narrow fissure still remaining along the middle of the nerve-groove.

The origin and course of the right vertebral artery in this subject, before it reaches the foramen, shew that the case falls to be classed with that interesting variety in which the right subclavian trunk arises last from the arch of the aorta, representing the remains of the embryonic right aortic root, four specimens of which are in my possession. One of these has the bones attached, and on both sides the vertebral artery is seen to enter at the foramen of the sixth vertebra, both arteries arising from the subclavian trunks a little earlier than

usual. In regard to the artery not normally entering the foramen of the seventh vertebra, the remark may be true enough that that would be out of its direct road, but it by no means follows that a lower origin of the artery will alter the result. It is very common for the left vertebral artery to arise from the aortic arch, between the carotid and the subclavian, but I have never yet seen it in such cases enter at the seventh vertebra. In endeavouring to understand this point one must think of where these arterial arches were in the embryo, not where they ultimately arrive at, and also of the early condition of the neck.

Case 3. *Left vertebral artery arising from the arch of the aorta, and entering at the fifth cervical vertebra.* The right was not noted, but both foramina of the 5th vertebra are equally full-sized and round, while on both sides of the 6th the foramen is scarcely half-size.

Case 4. *Right vertebral artery entering at the fourth vertebra, with other peculiarities.* Preparation of the four lower cervical vertebrae with the arteries. Although it was noted that the artery did not enter till the 4th, the foramina of the 5th and 6th are of good size and rounded, though not quite so large as those of the 4th. On the left side the artery entered at the 6th, but the anterior transverse processes of the 5th and 4th are deficient, a ligament bridging over the gap. Nevertheless, the anterior tubercles of these two transverse processes (supported from the posterior processes) are well developed, as are also their fellows of the right side and those of the 6th vertebra. Foramina of 7th oval and unequal; left not much less than the foramina above it; right about a third the size of the left.

Case 5. *Bony obliteration of the lateral foramen in the sixth vertebra, on one side.* Preparation of the six upper cervical vertebrae; moderately robust; no history. All the other foramina are full-sized and round. On the left side of the 6th, instead of a foramen there is a plate of bone. There is no mark, or thinness, to indicate a filled-up foramen. Anterior tubercle better developed than usual on this side; on the other side less than usual.

(f) ADDITIONAL FORAMEN IN THE CERVICAL TRANSVERSE PROCESSES. In 15 specimens of double foramen before me, in detached cervical vertebrae, other than the 7th or atlas or axis, nearly all, so far as appears, from different subjects, the double foramen is by the addition of a small one behind the ordinary foramen; except in one vertebra, in which, on one side, there is an hour-glass contraction marking off two foramina, of which the posterior is somewhat the larger. This frequent small additional foramen is situated opposite the middle, or a little external to the middle of the normal foramen, separated from it by a narrow bar of bone, sometimes only by projecting points, leaving it as a notch in the macerated bone. It is more or less straight in front, deeply convex behind, and therefore wants the rounded form of the great foramen. It varies much in size, in most about the size of the average foramen spinosum of the sphenoid, in some twice as large, in some reduced to the size of a thick pin. In nine of these specimens it is present on one side only, as it so happens in six on the right side, three on the left; in the remaining six on both sides, in three of them of about equal size on the two sides, in the other three considerably smaller on one side than on the other. It is largest in large-sized vertebrae, but is of good size in some that are not large. It is not formed at the expense of the greater foramen, although in some the latter may be a little less rounded at the dividing bar; nor do the two foramina, on the same side, appear to bear any relation to each other in size apart from the influence of the size of the bone. Thus the large foramina may be symmetrical while the small ones are not, and in the vertebrae in which it is present on one side only, the greater foramen is sometimes larger sometimes smaller than its fellow of the other side, as often the one as the other.

It is variously present as follows in 18 of the sets of cervical vertebrae before me.

1. On right side present, as a notch, in atlas, 3rd, 4th and 5th. On left side present in the four lower vertebrae, smallest in the 5th, in the 4th and 6th of good and equal size, and somewhat smaller in the 7th.

2. On right side in 5th and 7th, the intervening sixth ordinary foramen unusually large on this side. Left side, in atlas, 4th, 5th, and 6th, increasing downwards (vertebrae of case of ligamentous posterior arch of atlas. Case 2).

3. As a notch on both sides of 4th and 5th, and on right side of 6th and 7th. (Case of cervical rib No. 4.)

4. On both sides of 5th and 6th, and on left side of 4th, increasing in size downwards.

5. A young spine, 20 inches in length. As a notch, present on both sides of atlas, and on right side of 5th; on both sides of 6th, as a large foramen on right, as a large notch on left side.

6. As a small foramen on both sides of 5th; as a good-sized notch on left side of 6th.

7. Female subject, aged 17 years. In atlas on left side, and in 6th on both sides.

8. As a small foramen on both sides of atlas, as a notch on both sides of 6th.

9. In atlas on both sides, on right as a notch; and on right side of 6th as a foramen of good size. First dorsal vertebra on both sides presents a well-marked semilunar notch at the corresponding place. (Female subject, case No. 1 of lumbar variation.)

10. As a notch on both sides of atlas, on right side of 6th as a deep notch. Normal foramen much larger on this than on left side. (Case No. 4, lumbar variation, male aged 29.)

11. On both sides of 6th, right large, left small; and on left side of 7th as a notch. Robust spine. Atlas wanting.

12. As a notch on left side of 6th, and right side of 7th. (Case above noted in which right vertebral artery entered the 7th foramen.)

13. Preparation of two lowest cervical and first dorsal vertebrae. Present on both sides of 6th symmetrically as small foramen; on left side of 7th as a notch, and on right side of corresponding part of 1st dorsal vertebra as a notch.

14. On both sides of atlas as a notch, and on right side of 7th as a deep notch.

15. As a notch, on both sides of atlas and on both sides of 7th. Male subject (case No. 4 of thoracic variation).

16. Present on both sides in 4th, 5th, and 6th, on the 4th as notches only. On left side of 6th the anterior of the two foramina is the smaller, being about $\frac{1}{3}$ the size of the posterior. The latter, however, corresponds in position to the additional foramen in the vertebra above it. The artery has evidently not entered till the 5th on this side, and the aperture of the 6th has been minimised. The 7th vertebra carries ribs, and on both sides the lateral foramen shews a notch equal to the posterior third of an oval foramen. (Case No. 9 of lumbar variation.)

17. On both sides of 6th, as a notch. On left side of 7th as a foramen, oval transversely, long diameter $\frac{1}{8}$ inch, and from a third to a half less than the anterior foramen. On right side one foramen irregularly oval antero-posteriorly, like the two on the left side without the dividing bar.

18. On left side of 4th, as a notch; on right side of 5th as a notch. On both sides of 6th, on right side as a notch, on left side as a foramen larger than the one in front of it. The anterior small and oval, about the size indicated by the notch on the left side. The posterior three times the size of the anterior but not half the size of an ordinary lateral foramen. The vertebral artery, entering normally on the right side, has on the left side evidently not entered till the 5th, and the anterior foramen of the 6th has been minimised, and is bounded in front by a very thick anterior transverse process, about three times as thick as the corresponding process on the right side, or as the process of the vertebra above it.

Summing up these details, it appears that in these 18 subjects in which the posterior lateral foramen occurs, it is present in the *sixth* vertebra in 16 of them, on both sides in 8, on only one side in 8, of which 3 were on the right, 5 on the left side; and of the whole, the foramen was complete in 14, represented as a notch in 10. In the *seventh* vertebra it was present in 10, on both sides in 2, on only one side in 8, of which 4 were right, 4 left; and of the whole, the foramen was complete in 3, as a notch in 9. It may also be present in the first dorsal vertebra. In the *fifth* vertebra it was present in 8, on both sides in 6, on only one side, the right, in 2; and of the whole, it was com-

plete in 9, as a notch in 5. In the *fourth* vertebra it was present in 6, on both sides in 3, on only one side, the left, in 3; and of the whole, it was complete in 3, as a notch in 6. In the *third* vertebra, it was present in one alone, being on the right side only and as a notch. In none of my specimens is it present in the axis. In the *atlas* it was present in 9, on both sides in 6, on only one side in 3, of which 1 was on the right, and 2 were on the left; and of the whole it was complete in 5, as a notch in 10. Throughout the neck, in these eighteen subjects, it was 25 times present on both sides, 27 times on one side only; when present on one side only, it was the right side in 12, the left in 15; and in the whole, whether double or single, it presented itself 36 times as a complete foramen, 44 times as a notch.

Its *situation on the atlas*, it is to be remarked, is different, being separated from the normal lateral foramen by the posterior transverse process. It is, however, still in the course of the vertebral artery. It might be taken to be in the pedicle, but more strictly is formed by a bar of bone reaching from the posterior transverse process to the pedicle. Hence in the case of the atlas, in contrast with the lower vertebrae, the posterior boundary of the additional foramen is the more or less straight one.

(g) VARIATIONS OF THE SEVENTH CERVICAL VERTEBRA; LATERAL FORAMEN, TRANSVERSE PROCESS, COSTAL FACET. I refer here to the transverse process after the normal cervical rib, which exists in early life in the human body, is fully ankylosed.

The *foramen* is generally described as small, and the process as not bifurcated. It may be so perhaps most frequently, but it is very common to find the foramen as large as or larger than those in the vertebrae above it, and to find the transverse process with an anterior tubercle. The varieties of the foramen may be referred to two forms. In the one, it is small and more regularly formed, round or more or less oval transversely, the anterior boundary of the oval with a tendency to be less bent than the posterior. The bar of the anterior transverse process in front of the foramen is then generally thick. In the

other form, it is large and irregular in shape, but generally pointed externally, or prolonged as a fissure. The anterior transverse process is then generally slender and flattened and more or less bent forwards. But between these there are intermediate forms and some exceptions. The foramen may be as small in its long axis as $\frac{1}{12}$ inch, or as large as $\frac{1}{3}$, or even $\frac{3}{8}$ inch. A little over $\frac{2}{8}$ inch may be taken as the average transverse diameter of the lateral foramen in the other vertebrae, but it varies very much. Want of symmetry also is common, and probably this generally corresponds to difference in size of the right and left vertebral artery, the foramina above the 7th being generally functionally adapted. But want of symmetry appears to be more common in the 7th, as we should expect. In one set of cervical vertebrae before me, however, the foramina in the 7th are larger on both sides than those in the vertebrae above it, and are unusually oval in form and not very unsymmetrical. Although this foramen, or space, may be large and even not very irregular in form, it would not be safe to conclude that therefore the artery had passed through it. As noted above, it is not uncommon to find a notch at the back of this foramen, representing the additional foramen.

The *anterior transverse process* generally presents a rudiment of an anterior tubercle, and often a well-marked tubercle. The rudiment is represented by the ridge which bounds the nerve-groove internally, continued from the upper edge of the process. This ridge may rise upwards and outwards into a distinct anterior tubercle, giving the process a bifurcated character. There are before me seven specimens of bifurcation from well-developed anterior tubercle. Two of them are in young spines (each 20 inches in length), one of them with large oval foramen and slender anterior boundary, the other with middle-sized oval foramen and thick anterior boundary. Of the adult specimens, two have small foramina and thick anterior process; the other three have pretty large and well-rounded foramina. Even in the best developed it is narrow and pointed as compared with the tubercle of the sixth vertebra, the tubercle which meets the finger in the dissection of this part of the neck. In only one of my specimens (case of cervical ribs ankylosed on both sides—case 7a) is the anterior tubercle of the

sixth vertebra but slightly developed, and that on the right side only, and the foramen on that side is very small, while it is full-sized on the other side and in all the vertebrae above.

Costal facet. According to my observation it is rare to find a facet on the 7th cervical vertebra for articulation with the head of the 1st thoracic rib, more rare than the expressions in books imply. Apart from cases of supernumerary cervical rib, it is present in only two of my specimens, and that on one side only; one on the left side, one on the right. In the latter, the facet is about half the size of the neighbouring one on the 1st dorsal vertebra. The head of the 10th rib articulates with the 9th vertebra in this case also on the right side, but not on the left. In the other case, the 10th rib does not touch the 9th dorsal on either side. It is, however, common among quadrupeds to have the 1st rib articulating with the 7th cervical vertebra as well as with the 1st dorsal, and as the foramen is often wanting at the same time, this vertebra then has not the character of a cervical, and has the character of a dorsal, according to the definitions of human anatomy.

(h) CERVICAL RIBS. I shall notice my various specimens in the order of development.

Case 1. *Preparation shewing rudiments of Cervical Ribs on the 6th and 7th vertebrae, in a male subject aged four years.* The preparation includes the cervical vertebrae, and the first four dorsal vertebrae with their ribs. On the *sixth* vertebra the cervical rib, or separate bony element, forms the lower part of the anterior transverse process, and is the same on both sides. It is separated from the process proper by an oblique suture, seen both before and behind, running downwards and outwards, dividing the wall of bone nearly equally, so that the rib is broad internally where it rests on the body, and tapers outwards to nearly as far as the end of the anterior process proper. Total length $\frac{5}{12}$ inch. As seen from below, it rests against the anterior half, as seen from above against the anterior third, of the body, the neural arch resting on the posterior part. Both rib and neural arch are seen to form the lateral part of the intervertebral "body" surface, above and below. The anterior transverse process proper is, like the pos-

terior, ossified from the neural arch. It passes forwards and outwards behind and above the rib, and meets the posterior at the outer end of the well-marked foramen, at the fore part of the nerve-groove, a very little way external to the apex of the rib. Thus a foramen is completed by the two processes quite irrespective of the rib, although the back of the latter forms the lower part of the front wall of the foramen. A small additional foramen exists behind the normal foramen on the right side, no other vertebra of this neck shewing it. The 5th vertebra shows, and indeed the 4th, 3rd, and 2nd also show, on their under aspect, traces as if from fissure between the fore and back parts of the arch where it rests on the sides of the body, but these are not reliable.

On the *seventh* vertebra, the rib or additional element is differently placed, being farther out and not reaching in to touch the body of the vertebra. The neural arch rests against the whole side of the body, from before backwards, sending out a broad anterior process in front of the foramen to meet the posterior process, which has turned round far enough to form the outer end of the foramen and the outer half of the nerve-groove. The rib reaches outwards as far as the tip of the posterior transverse process, and, tapering inwards, ceases $\frac{1}{4}$ inch from the body proper, reaching as far in as opposite the inner end of the foramen. Total length of rib $\frac{5}{12}$ inch. The rib is broadest about its middle, forming two-thirds of the breadth of the compound anterior transverse process, and the suture which unites it to the two transverse processes is very irregular. This applies to the left side. On the right side, my notes, made in 1857, state that "a ligament completed the foramen. No separate bony element existed here." The ligament has perished, the broken points of its attachment remaining visible, opening up what has been a foramen about the same size as that on the left side.

Case 2. *Moveable Cervical Rib, developed to the extent of head neck and tubercle, on both sides, in a female subject aged 7 years.* Preparation of two lower cervical vertebrae and two upper dorsal vertebrae with their ribs. In contrast with the last case, these ribs form the entire anterior boundary of the

foramen. They represent the head neck and tubercle of a rib, and pass about $\frac{1}{4}$ inch beyond the tip of the transverse process. They are nearly symmetrical, the left a little broader and more marked with a nerve-groove, the right passing a little farther beyond the tip of the transverse process. Total length $\frac{7}{12}$ to $\frac{8}{12}$ inch. A conical parapophysis, $\frac{1}{8}$ inch in length, rises from either side of the body, upon the end of which the obliquely cut head of the rib is movably articulated. The foramen, or space, which they bound is, on the left side, chiefly formed by a deep notch in the posterior process and is of moderate size, on the right side more shallow and smaller. Beyond this they are moveably articulated, for $\frac{1}{3}$ inch, to the posterior transverse process. Greatest breadth of rib here, right $\frac{2}{12}$, left $\frac{3}{12}$ inch. The sixth vertebra presents a normal lateral foramen on the left side, about twice as large as that of the 7th, but a very small one on the right, smaller than that of the 7th.

Case 3. *Similar to the last.* Preparation of a young spine, in section, about 20 inches in length. All the other vertebrae and ribs normal. Conical parapophysis $\frac{1}{8}$ inch long, against which head of rib is movably articulated. Neck of rib bounds a large foramen on both sides. Costo-transverse articulation for $\frac{1}{4}$ inch, and ribs project $\frac{1}{4}$ inch beyond tip of process. Ribs expand opposite and beyond their external articulation. Left rather the largest but nearly symmetrical. Total length $\frac{7}{12}$ to $\frac{8}{12}$ inch. Greatest breadth at outer end $\frac{3}{12}$. Neck and head are more flattened than in the last case.

Case 4. *Cervical Rib, to the extent of head neck and tubercle, free on right side, ankylosed on left. Position of arteries and nerves.* Adolescent subject, the body epiphyses not being united, and the tips of the spinous processes cartilaginous. Preparation now presents the cervical vertebrae with the first dorsal vertebra and its ribs. Cervical rib on right side to the extent of head, neck, and tubercle. Length nearly 1 inch. Rather more than the inner half is a narrow bar $\frac{1}{12}$ to $\frac{1}{8}$ inch broad; outer part suddenly enlarged to a breadth of $\frac{4}{12}$ where it rests on the posterior transverse process, presenting a triangular mass which tapers outwards to a distance of nearly half an inch beyond the transverse process. Rib was articulated at

both its costo-vertebral and costo-transverse connections by cartilage, allowing of motion. Head rested on a parapophysis $\frac{1}{6}$ inch in length, flattened, and extended vertically at its root. Neck of rib shews a nerve-groove on which the 7th cervical nerve was seen to rest. Internal to this it becomes flattened, expanding at last, vertically, to a breadth of $\frac{1}{6}$ inch where it meets the parapophysis. On left side, rib completely ankylosed, leaving no kind of trace internally, nor any externally except that an undulation seems to mark off where the triangular tubercle has joined the posterior process. The tip of the now united mass does not reach so far outwards, by nearly $\frac{1}{4}$ inch, as the tip of the rib does on the right side. The bar in front of the foramen is more flattened at the nerve-groove than the neck of the rib on the right side is.

The right vertebral artery divided immediately at its origin, half an inch below the level of the 7th foramen; the posterior, rather the smaller, entered the 6th foramen, and the two re-united between the 6th and 5th foramina, the artery then having the usual course. The left vertebral artery arose normally and entered the 6th foramen. Arising behind it from the subclavian was a small artery, about $\frac{1}{4}$ its size, which entered the 7th foramen, but was lost between the 7th and 6th foramina. In the now macerated bones the left 7th foramen is oval and rather large, being 4 lines in its long diameter, and rather more capacious than the rounded 6th foramen above it. The foramen, or costo-vertebral space, on the right side is larger and elongated outwards into a narrow apex. The narrow outer part was occupied by fibrous tissue; the larger part was closed by a fibrous membrane, the naturally perforated part of which was under a line in diameter. The notches representing the additional foramina in this neck are noted under that section, case 3. The notch for the posterior foramen on the right side of the 6th vertebra is large, about $\frac{1}{2}$ to $\frac{1}{3}$ the size of the anterior foramen (through which the posterior division of the vertebral artery probably passed), which again is considerably less than that of the 5th through which the re-united vertebrals passed. The 6th foramen on the right side has the full size.

Case 5. *Cervical Rib, to the extent of head neck and tubercle,*

free on left side, ankylosed on right. Female aged 40. Preparation of entire spine with 1st and 12th thoracic ribs. Length of cervical rib $1\frac{1}{4}$ inch. Projects over $\frac{1}{2}$ inch beyond transverse process. Head flattened and rests in a facet upon a short thick parapophysis projecting from upper part of side of body. Joint was surrounded by ligament and presented cartilaginous surfaces and a cavity. Costo-transverse joint $\frac{5}{8}$ to $\frac{6}{8}$ inch long, and when opened presented cartilaginous facet $\frac{4}{8}$ inch long, transversely, by $\frac{1}{8}$ broad. The facet was at the lower and outer part of the connexion, the rest being strong interosseous ligament. Nerve-groove double. Foramen a moderate-sized oval space internally, half the size of the right foramen, prolonged as a narrow fissure externally which an interosseous ligament occupied. Vertebral artery entered on right side at 6th, on left side at 4th. Left foramen of 6th undersized, of 5th small. On the right side the lines of union have disappeared; tip projects $\frac{1}{4}$ inch less than that of rib on other side. Nerve-groove single. First thoracic rib seems as if it had touched 7th vertebra, at least on right side, but there is no real notch. Other peculiarities of this preparation are,—12th thoracic ribs small, left the shortest. First coccygeal bone ankylosed to sacrum. Atlas has posterior bridge on both sides, (case 4 of that variety).

Case 6. *Cervical Rib, to the extent of head neck and tubercle, on left side, ankylosed externally on right.* Preparation of cervical vertebrae, adult and otherwise fully ossified except that the laminae of the atlas have not quite united behind. (Already referred to with case 3 of that variety.) On *right* side a fissure remains between head of rib and a well-marked flat tapering parapophysis, which projects from above the middle of the body. Head of rib here thin and $\frac{1}{10}$ inch in breadth. Is bulged forwards with large foramen. Moderate anterior tubercle, succeeded by broad and deep nerve-groove. Externally no reliable trace of ankylosis remains above, but line is distinctly seen on under surface. United mass tapers to a point outwards and forwards, 5 lines beyond transverse process. Foramen large and rounded with addition of a narrow part externally, the rounded part as large as that of the 6th, which is large on both sides. *Left side.* Rib now lost. Vertebra shews two smooth

facets where the rib has articulated; one on the well-marked parapophysis, $\frac{1}{6}$ inch vertically by $\frac{1}{12}$ in breadth; the outer, on the anterior edge of the transverse process, $\frac{1}{4}$ inch in length by $\frac{1}{8}$ in height, facing forwards and outwards. The transverse process is a little shorter and more pointed than the part referable to the transverse process on the other side. The foramen has been about half of that of the right side, as indicated by the deep oval notch.

Case 7. *Two cases of Cervical Ribs, to the extent of head neck and tubercle, ankylosed on both sides.* (*a*). Adult female. The elongation and curved form of the transverse processes shew that cervical ribs have existed here prolonged for about half an inch beyond the transverse processes proper. Although there is no mark like a suture, one can readily see, by the undulation and the direction of the part beyond, where the union with the process has taken place. The tip of the left is 1 inch, measured straight, from the body of the vertebra, that of the right over $\frac{3}{4}$ inch, its tip being more curved in and more pointed than that of the left. They project beyond the tip of the posterior transverse process of the 6th, on the right side 3 lines, on the left side 5 lines. Anterior boundary of foramen straight and rather thick on left side. Nerve-groove well marked. Foramina oval; left about as capacious as the rounded foramen of the 6th above it; right somewhat larger with a point externally, and thrice the size of the foramen of the 6th above it, which is small, that of the 5th being full-sized. The 7th vertebra has on its right side what seems to be a true notch for the head of the first thoracic rib, not merely a mark for the ligament.

(*b*) Also from an adult female, and so closely resembling the last case as scarcely to require separate description. In this case the right is the longest, the tip fully 1 inch from the body, that of left $\frac{7}{8}$ inch. Projection beyond posterior transverse process of sixth, right side 6 lines, left side 4 lines. Foramen of left side oval and smaller than foramen in sixth; on right side elliptical and large, $\frac{3}{8}$ inch in length and over half of that in breadth at the middle. Anterior boundary of foramen more slender, and has better marked nerve-groove than on left side, and presents a small anterior tubercle.

Case 8. *Loss of Cervical Ribs causing apparent want of the foramen in the seventh vertebra.* The nature of such cases is evident, the rib having been lost in maceration the lateral foramen appears to be wanting. A good instance of this is seen in a full-grown male skeleton in the Anatomical Museum of the University. The facets for the head and tubercle of the missing cervical ribs are well marked on both sides. The smooth facet on the end of the short parapophysis is round and about $\frac{1}{8}$ inch in diameter on the left side, vertically oval on the right; the facet on the transverse process is rounded, concave, $\frac{1}{4}$ inch in diameter, and placed on the lower half of the outermost part of the front of the process, facing forwards and a little outwards. The outer edge of this facet is 1 inch from the body of the vertebra. One would infer from the size and completeness of the facet, and from the robustness of the transverse processes to their end, that the lost rib had been developed some way beyond the tubercle. Although the normal foramen is thus wanting, there is what might have been mistaken for it in a reduced condition, the notch of an additional foramen on both sides, that on the right side nearly completed into an oval foramen $\frac{1}{8}$ inch in its long diameter. This additional foramen is present, on the left side, also in the 6th and 5th, and on the right side in the 4th and 5th, in the latter as a deep notch. (This case is in addition to the 16 cases given under that variety.)

The various forms presented by the transverse process, or what is included in that term, of the 7th vertebra are understood by referring to the various degrees to which the normal cervical rib of early life may be developed before becoming ankylosed,—when it gets well in front of the outer end, increasing the process in breadth, antero-posteriorly; when it passes beyond it, increasing the length of the process and giving it a curvature forwards; and, it may be, increasing the robustness of the process proper, both antero-posteriorly and vertically, to give support and surface for articulation. The varying conditions also of the neck of the rib farther affect variously the size and form of the foramen, so that, in fact, it is not easy to get two seventh cervical vertebrae whose transverse processes are exactly the same[1].

[1] The seventh cervical vertebra is well known to vary much in different groups of the mammalia in regard to the presence or absence of the "perfora-

The preceding seven cases of cervical rib, occurring to the extent of what may be termed its vertebral or posterior stage, illustrate a condition which I believe is more common than appears to be generally supposed. From the situation of the part and the mode of proceeding in dissection, this particular region is apt to be left over and afterwards neglected. Were it looked for, I believe that these short cervical ribs in a non-ankylosed condition, or ankylosed after abnormal prolongation, would be more frequently found.

I have spoken of these cases as representing only the head neck and tubercle, the short stump projecting beyond the transverse process hardly deserving to be regarded as shaft. I now proceed with the cases in which the cervical rib was developed in its middle stage or shaft, or also in its anterior or sternal stage.

tion" in the transverse process. It was found by Professor Owen not to be present in the *Gorilla*, but in that of an adult male gorilla in my possession there is a large oval foramen on the right side, bounded in front by a slender bar of bone, in most of its length as narrow as a small-sized pin. On the left side the narrow part is wanting, apparently not broken, leaving a deep oval notch which would have formed a smaller foramen than that on the right side. On the right side at least, the foramen is larger than, though not so round as, the foramen in the 6th vertebra. The Atlas of this gorilla, I may mention, presents natural deficiency of most of the anterior transverse processes, especially on the left side. It is not usually present in the *Horse*, but in a horse in the Anatomical Museum of the University, the foramen is present on the right side and is fully as large and as rounded as that of the 6th vertebra, and bounded below by as thick a bony wall, fully ankylosed. The transverse process beyond is thickly bifurcated; the superior part prolonged backwards; the inferior projecting forwards, and also continued backwards on the body of the vertebra. The left side has neither foramen nor inferior process. In a specimen from a *Sheep*, which I picked up on the hills, the foramen is present. The preparation now before me, includes the 6th and 7th cervical vertebrae, and the 1st dorsal with its ribs. On the right side, the foramen is rounded and about half the size of the foramen of the 6th, and is bounded below by a strong completely ankylosed bony wall; on the left side it is bounded below by a narrow ligament, leaving an equally large but oval perforation. The body epiphyses of these vertebrae are not yet ankylosed, and an epiphysis is seen on the back part of the free edge of the inferior transverse process of the 6th, on the left side, this part on the right side having been destroyed. The foramen is not normally present in the *Elephant*, but in the skeleton of an adult Indian elephant in Dr Barclay's Museum, in the keeping of the Edinburgh College of Surgeons, from which I was in the habit of delivering my lectures on the osteology of the elephant, the foramen is present on the right side, the inferior boundary, however, not joining the body of the vertebra, a gap of ½ inch intervening. On the left side there is a deep notch. I have twice noticed in not full-grown elephants a well-marked notch corresponding to the back part of this foramen. In one of the two *Camels* in the Edinburgh College of Surgeons Museum (camelus dromedarius) the foramen is present on the right side, and I noticed it present on the right side in a camel (camelus dromedarius) in the excellent Anatomical Museum in the University of Jena. The variety occurring in the camel is of further interest, considering the position of the foramen, or canal, in the five middle vertebrae of the neck in that family.

Case 9. *Cervical Rib developing a shaft and resting by its anterior end on a conical process of the first thoracic rib. Recognised by me during life.* The cervical rib and the first thoracic rib were removed at the post-mortem examination. From a young woman, left side. As to the right side I can only now say that I do not recollect that there was any thing there to attract attention. The *first thoracic rib* is well formed, measures 4¼ inches along the outer edge, 3 inches straight from end to end, at the furthest points, and ⅝ in breadth before and behind the base of the conical process; and it has a good cartilage at its sternal end. *Cervical rib.* Total length 2½ inches, of which 1½ belong to the shaft. Presents head, neck, and tubercle fully as distinctly formed as those of the first thoracic rib, the neck broader and thinner, and the tubercle more projecting owing to the narrowness of the shaft. Shaft narrower than neck but more rounded; breadth of shaft ⅕ inch, thickness ⅛. An elevation about the middle of the upper surface marks off two grooves, each as broad as the little finger, the anterior best marked, and here I infer that the subclavian artery lay. In front of this groove the rib forms a rounded button-like terminal expansion, ⅜ inch in diameter, ⅜ in thickness. The shelving outer half of this expansion articulates moveably with the blunt apex of the conical process, having the appearance as if there had been a cavity surrounded by a strong capsular ligament, the latter, however, deficient on the pleural aspect. The two ribs are over half-an-inch apart. *Conical process* on first thoracic rib, length ½ inch; breadth at blunt apex ⅜, at its expanded base about ¾, but limit not very definite as the anterior border runs very obliquely into the inner border of the rib. The cone is thick and triangular, inner surface rising from the inner border of the rib, the edge between the anterior and posterior surfaces reaching some way on the upper surface of the rib. The process is situated two inches in front of the tubercle, and 1¼ inch from the anterior end of the bony rib.

Case 10. *Cervical Rib on both sides; on right side, shaft resting by its anterior end on conical process of first thoracic rib; on left side, shaft prolonged to sternal connection.* Female aged 65.

Vertebrae normal throughout, except that 7th carries the cervical ribs. Besides, there are the twelve thoracic ribs, the 12th pair about 3 inches in length. The three last coccygeal bones united, the first moveable. *Ribs and their anterior connections.* The cervical rib on the *right side*, the shorter of the two, has a close resemblance to the cervical rib in the case last noticed. Length of head neck and tubercle, $1\frac{1}{8}$ inch. Shaft also $1\frac{1}{8}$, and very like another head and neck turned forwards, nearly at right angles, but more rounded in form. Neck at middle $\frac{1}{4}$ inch broad, $\frac{1}{10}$ thick; shaft at middle $\frac{1}{4}$ broad, $\frac{1}{5}$ thick. Breadth of rib at its tubercle $\frac{1}{2}$ inch. Shaft on upper surface is on the whole convex, bending down to meet the conical process; a groove in front of tubercle corresponds to position of 1st dorsal and 8th cervical nerves, and there is a very shallow groove at the fore part. Anterior end enlarges a little, to 5 lines in breadth and 4 lines in thickness, and rests abruptly against hinder aspect of top of conical process of first thoracic rib. The joint between them presents a strong capsular ligament, but nearly wanting on the pleural aspect. End of rib notched, partially embracing top of conical process, part on sternal side but most rests on the flat facet of the process which looks upwards and backwards. Upward and downward motion free. Synovial cavity present and both surfaces smoothly cartilaginous. Upper $\frac{1}{3}$ of conical process composed of cartilage. Length of process at middle $\frac{1}{2}$ inch, more on sternal side, less behind. Breadth at middle 5 to 6 lines, at top 4 to 5 lines, at base about $\frac{3}{4}$ inch but not exactly defined. Thickness, in all its length, nearly 4 lines. Pleural surface flat, rising from the rounded-off inner border of the rib, outer surface convex. First thoracic rib,—breadth in front of conical process 8 lines, behind it 5 lines. Length of head neck and tubercle $1\frac{1}{4}$ inch; of shaft along outer edge $3\frac{1}{2}$, along middle $3\frac{1}{4}$. Length of costal cartilage, upper margin 1 inch, lower margin $1\frac{1}{2}$. Breadth at middle 7 lines.

Left side. Cervical rib; length of head neck and tubercle $1\frac{1}{8}$ inch. Length of shaft 2 inches. Thinner than right, breadth at middle over $\frac{1}{4}$ inch, thickness $\frac{1}{8}$. The anterior groove, where the subclavian artery lay, is well marked, its middle is $1\frac{1}{4}$ inch in front of hinder edge of tubercle. This groove is deepened in

front by the development of a scalene process, in the form of a low triangular elevation from inner margin of rib, to which the anterior scalene muscle is attached. Breadth of rib at this process, $\frac{1}{2}$ inch. At the front of this process, but $\frac{1}{4}$ inch further at the lower edge, the rib ceases to be bony, and is prolonged as cartilage, $1\frac{1}{4}$ inch in length, $\frac{1}{4}$ in breadth, till it reaches and blends with the upper part of the cartilage of the 1st thoracic rib. There is a break in this narrow cartilage, $\frac{1}{2}$ inch from the anterior end of the rib, which shews a kind of cavity when cut into, but, although it is very like a joint, I will not aver that it is not a fracture. First thoracic rib.—Head neck and tubercle $1\frac{1}{4}$ inch. Length of shaft $4\frac{1}{2}$ inches along outer edge, 4 along middle. Breadth towards back 6 lines, increasing forwards to 8 lines. Length of cartilage of this rib, at lower margin $1\frac{1}{2}$ inch, at upper part before it unites with the cartilage of the cervical rib, $\frac{1}{2}$ inch; length of united cartilage $\frac{3}{4}$ inch. Breadth of united cartilage at the middle $\frac{3}{4}$ inch, thickness $\frac{1}{5}$.

Connection with the vertebrae. Costo-vertebral joint. The two cervical ribs rest entirely on the 7th vertebra. The left had a capsular ligament allowing free gliding motion. Within this a synovial cavity with not very smooth cartilaginous surfaces. Shelving head rested obliquely on front and end of a short parapophysis. On right side, an oblique ligament passed from the head to the fibro-cartilage above; a strong ligament, $\frac{1}{4}$ inch thick, passed down to the head of the first thoracic rib, preventing the two heads from being separated farther than $\frac{1}{4}$ inch; and between these a capsular ligament bound the convex head into a socket which lies very close to the socket for the head of the rib below. The first thoracic ribs rest in part on the 7th cervical vertebra by rounded heads, and had a stellate ligament, but I saw no inter-articular ligament. Synovial capsule present and rather spongy cartilaginous surfaces. The costo-transverse articulation on both sides presented synovial cavity and smooth cartilaginous surfaces, transversely oval and $\frac{1}{3}$ inch in length; above the facet a transverse fissure into which a ridge of the rib fitted; and strong ligamentous fibres existed externally all round. Tips of transverse processes still covered with cartilage.

Muscles connected with the cervical ribs. On the right side

only the external *intercostal* muscle was present, the space 1 inch in length, $\frac{1}{3}$ inch in height. On the left side, the space $3\frac{1}{2}$ inches in length by under $\frac{1}{2}$ inch in height; the internal intercostal also was well developed, with the usual absence of the internal at the back part and of the external at the fore part. The *scalenus anticus* was, on the left side, attached to the process above noted on the cervical rib, having the subclavian artery behind it. On the right side the muscle had been torn, the remains of its insertion being on the end of the cervical rib and on the conical process of the first thoracic rib. This process, occurring so often in cases of cervical rib extending only to this extent, may be looked on as the normal scalene tubercle, or process, of the first thoracic rib in a more developed condition. The muscle having been torn through, and the subclavian artery displaced, I could only infer that on this side also the artery lay behind the scalenus, but there is only a very shallow groove on the rib here. The *scalenus medius* was attached partly to the first thoracic rib, partly, about half of it, to the cervical rib, the insertion beginning just in front of the tubercle and extending for $\frac{3}{4}$ inch outwards on the shaft. The part of the scalenus medius which comes from the 6th transverse process was detached as a separate muscle, forming a *levator costae* to the cervical rib. It was about the size of an ordinary levator costae muscle, larger on the left than on the right side. Arising from the lower edge of the posterior transverse process, it passed downwards expanding to be inserted into the cervical rib at the outer part of the neck and extending to beyond the tubercle. The back part of it, separating from the rest, was inserted into the 7th transverse process, representing a *posterior inter-transverse muscle.* The anterior *inter-transverse muscle* was a small and flattened but very distinct bundle, $\frac{5}{8}$ inch in length, $\frac{1}{8}$ in breadth, arising from the lower edge of the anterior process, inserted into the fore part of the upper surface of the neck of the cervical rib, nearer the tubercle than the head. The 7th nerve passed out between this muscle in front and the cervical levator costae and posterior inter-transverse muscle behind. A muscle appearing as a levator costae to the first thoracic rib arose partly from the 7th transverse process but mostly from the cervical rib external

to the tubercle, concealing the back part of the external intercostal proper. The only other muscle attached to the cervical rib was, to its tubercle, the ascending tendon of one of the long muscles of the back, its lower connections not seen.

The right *vertebral artery* arose from the subclavian opposite the mammary, an inch from the bifurcation of the innominate, and entered at the 6th foramen; the left arose from the arch of the aorta between the left carotid and subclavian, and after a course of four or five inches entered the foramen of the 5th vertebra. It is of good size though somewhat less than the right. The deep cervical artery, on both sides, passed back between the cervical rib and the first thoracic rib. The 8th cervical and 1st dorsal *nerves* passed across the upper surface of the cervical rib, uniting on it, and resting on a shallow groove on the inner side of the back part of the shaft, the 7th nerve passing obliquely across the front of the neck.

(i) Recognition of Cervical Rib in the living body. Surgical and Hereditary aspects. When a cervical rib is developed some way beyond the vertebra it assumes a surgical importance. The projection may be mistaken for a morbid growth, and the pulsation of the elevated artery might at first be taken for a commencing aneurism. The late Professor Syme was familiar with the condition, under the name of exostosis of the first rib, and I remember his mentioning to me in 1853 the case of a medical man who had come to consult him in great alarm under the impression that he had discovered an aneurism of his subclavian artery.

1. The case No. 9, above related, occurred to me when I was surgeon to the Edinburgh Infirmary. The patient was under treatment for some internal complaint when I was asked to see her on account of the tumour at the bottom of the neck, and I had no difficulty in recognising the nature of the case. There is no reason why this variety should not, like other varieties be hereditary, and as the condition admits of being recognised in the living body, the question of its hereditary transmission admits of being determined. For the following two cases in which the cervical rib was recognised during life

by them, I am indebted to the gentlemen whose names are mentioned.

2. *Case in which a Cervical Rib was recognised in the living body by Mr Wilkes, of Salisbury, reported to me by him.* E. H., a woman aged 56, admitted to the Salisbury Infirmary, August 1874, under Mr Wilkes' care, suffering from chronic disease of the right shoulder-joint. She is very thin, rendering the parts distinct. Mr Wilkes noticed a very *prominent knob* in the middle of the *left* posterior triangle, and recognised it to be a cervical rib, an opinion in which his colleagues concur. The prominence ends as a knob of bone, the size of the last division of an adult man's thumb; projects boldly outwards and forwards, and from the under surface of the knob a hard continuation can be traced to a part beneath, apparently the first rib. Distance of knob from spine of 7th cervical vertebra, $4\frac{1}{2}$ inches; from middle line of neck in front, 3 inches; from centre of clavicle, arm natural, 2 inches; when arm is raised, 1 inch; from the knob to the left sterno-clavicular articulation, $3\frac{1}{4}$ inches; to the end of the acromion 5 inches.

The *subclavian artery* seems raised quite two inches above the clavicle, and is most dangerously situated for injury. In its third stage, traced upwards and inwards from the middle of the clavicle to the knob, the artery is seen pulsating, as if subcutaneous, and might easily be mistaken for an aneurismal dilatation. Above and external and somewhat posterior to it are felt the cords of the brachial plexus of nerves. In the situation of the knob the pulsation is lost, leaving the position of the artery here uncertain. To the inner side of the scalenus anticus, is felt the connecting bond between the cervical rib and the first thoracic rib, and then the first stage of the artery, outward pressure on which stops the circulation in the third stage and also the radial pulse. The external jugular vein passes downwards and inwards across the middle of the front of the prominence. In the *right* posterior triangle, on this side, as on the other, on a level with the 7th cervical vertebra, there is a similar prominence, much less developed, but enough to produce a more than usual fulness at this part of the neck. The artery is more deeply seated and as if smaller on this side,

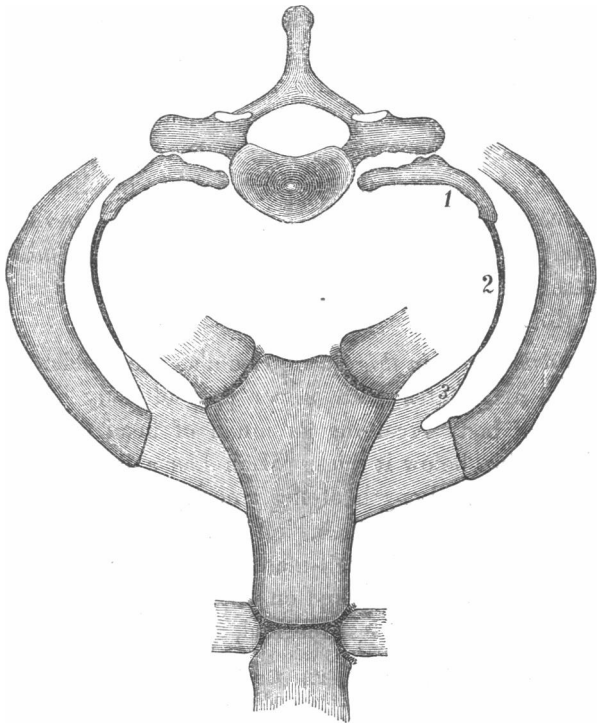
and elevated above the clavicle about an inch and a half. The patient has had the prominence as long as she can remember and has never had pain in it. Mr Wilkes has most kindly also sent me photographs of the neck, which shew quite plainly a conical projection on the left side in the situation described by him. He considers the state of parts to be similar to that presented by the specimen in my case No. 9.

3. *Case in which a Cervical Rib was recognised in the living body, by Dr Housley, of Lincoln, reported to me by him.* B. W., a man aged 25. In February 1873, when examining this patient's chest, Dr Housley noticed an unusual appearance on the right side of the neck, and on farther examination recognised it to be a case of cervical rib. The right subclavian artery is higher than the left when the clavicles are on the same level, and the pulsations are distinctly visible on the right but not on the left side. A cervical rib cannot be detected on the left side. The man has brothers and sisters who reside at a distance, but Dr Housley has most kindly examined those of the relatives who are within his reach—the mother, his children, one brother and his children—but found no trace of cervical rib in any of them. I expect however that it will fall to some one before long to meet with a case of hereditary transmission of this condition.

(B) VARIATIONS IN THE THORACIC REGION.

(a) IMPERFECT CONDITION OF FIRST PAIR OF RIBS. Male subject aged 24. This case occurred in 1852, and the accompanying drawing of it is that which I published in 1853. There is no absolute certainty that it was not a case of supernumerary cervical rib. It was noted that it was carefully ascertained that there were only eleven other pairs of ribs, but it is possible enough that the presence of a rib on the 7th cervical vertebra may be accompanied by the absence of one on the 12th dorsal. It is also noted that the anatomy of the scalene muscles and subclavian vessels was normal, but this is not altogether incompatible with the supernumerary view. The general appearance of the supporting vertebra suggests a first dorsal rather than a 7th cervical, but the ordinary differences between these two

vertebrae when normal, are just those which one would expect to be affected by the occurrence of one or other of the two



1. Rudimentary rib. 2. Ligament.
3. Small cartilage becoming blended with cartilage of next rib.

varieties—viz. the size and direction of the transverse processes, the form of the body and the somewhat variable length of its lateral elevations, the costal facets, and the slight differences between their upper and lower articular processes. The relation of the cartilages to the manubrium seems to favour the supernumerary view, but that also will be seen below to be compatible with either view[1]. The head had been removed, and

[1] By the kindness of Prof. Rokitanski I was enabled to make a note of a specimen of imperfect development of the first thoracic ribs, in the Pathological Museum of Vienna, which throws some light on this point. The whole of the cervical vertebrae being present there is no doubt as to the case being

[See description of similar case on subsequent pages of this number of the Journal.]

there is at least no record as to the lumbar vertebrae. I was perhaps more easily satisfied then than now, but with the question before me when the dissection was under observation, I was led to conclude that the case is one of imperfect first thoracic rib. With such doubts, the question occurs whether some of the cases which it has been customary to regard as instances of supernumerary rib, but in which the whole neck vertebrae were not examined, may not have been cases of imperfectly developed first thoracic rib. It is possible that case No. 9 of cervical rib, above described, may have been of that nature, but the appearances during life, and the resemblance to other cases, seemed to entitle it to be regarded as a case of cervical rib[1].

Note of the parts in this case. See also the woodcut. Head of each *rib* articulates with upper part of body of vertebra, lower part of body receiving as much of head of 2nd rib as body of vertebra below it does. Each has a good costo-transverse articulation. Length of head neck and tubercle 1 inch; length of shaft, right 1 inch, left 1¼. Left shews near its slightly expanded end a well-marked groove where the subclavian artery lay, best marked on the inner side; right shows groove on inner side but less marked, and very slightly marked

one of imperfect first rib. (No. 2882.) On left side, rib goes about ⅔ round, and articulates with a process of the second rib. On right side, it joins second rib at from ½ to 1 inch beyond tubercle, but again projects as a curved process where the subclavian artery has passed over it. The manubrium sterni first receives a broad cartilage, as if from one rib only, and, secondly, a cartilage at the junction of the manubrium and body, which is the cartilage of the *third* thoracic rib.

[1] *Case of imperfect first thoracic rib in a three-toed Sloth.* In a three-toed sloth (Bradypus tridactylus) in my possession, the first thoracic rib is very incompletely formed on one side. The *ninth* cervical vertebra shows, on the left side, its square-shaped rib, ¼ inch in length, resting abruptly on the transverse process; on the right side, it is ankylosed, the line of ankylosis barely recognisable; and there is no inferior transverse process or foramen. The *eighth*, besides the foramen, has the well-bifurcated transverse process; and, on the right side, the end of the blunt superior transverse process looks as if it had supported a rib, while that of the left side is flattened and tapers to a point. The *first thoracic rib* is complete on the left side, with its double implantation on the 10th vertebra, and meeting in front, but not ankylosed to, the lateral process of the presternum. On the right side this rib begins by head and tubercle attachments, but its shaft is only half an inch in length and terminates, in the macerated bone, by an irregular blunt end; thus presenting an approach to what might be called a 3rd cervical rib and a 10th cervical vertebra. The rather deficient right lateral process of the presternum ends in a short tapering cartilage, which terminates on and adheres to the second thoracic rib near its anterior end. The wanting two-thirds of the shaft may have been represented by cartilage and ligament.

on upper aspect. Breadth of each at the tubercle 5 lines, of shaft at middle 3 lines, thickness 2 lines, but left rib the largest all along. A *ligament*, narrow but strong, 2 inches in length, passes forward from the tip of each rib and joins the pointed hinder end of a narrow cartilage. This *cartilage*, 1 inch in length, $\frac{1}{4}$ inch in breadth, joins the upper part of the manubrium, and by its lower edge is in contact and apparently fused with the cartilage of the second rib, earlier on the right than on the left side. *Second pair of ribs.* Length of shaft 6 inches along middle, along outer edge $6\frac{3}{4}$. Average breadth 8 lines. Rough mark for serratus magnus muscle well developed, breadth here 10 lines. This gives a length of shaft 1 to $1\frac{1}{2}$ inches less than that of 2nd rib in four male specimens before me, and about 2 inches more than that of the first rib in the same skeletons. Transverse diameter of thorax between edges of 2nd ribs, almost 6 inches. Same of the other specimens, $6\frac{3}{4}$. Superior aperture of thorax, as bounded laterally by the rudimentary ribs and their prolongations, transverse diameter $4\frac{1}{2}$ inches, antero-posterior $2\frac{1}{4}$, which is fully equal to that of an average male thoracic inlet.

The *manubrium sterni*, as marked off by the non-union opposite the cartilage of the third rib, is longer than usual, 3 inches in length, while the body is shorter than usual, $3\frac{1}{4}$ inches, the more usual proportions being 2 to $2\frac{1}{2}$ and about 4. From the 3rd cartilage downwards the pieces of the body of the sternum are quite united, and receive the next four cartilages in the usual way. Cartilage of the 8th rib runs to the ossifying appendix, $\frac{1}{4}$ inch below the sternum. The increased length of the manubrium is not gained between the 3rd and 2nd cartilages, but opposite the broad united cartilage of the first two ribs, this cartilage being $1\frac{1}{2}$ inches in breadth, obliquely, along the line of its union with the sternum. The whole of this cartilage has an oblique slope downwards and inwards to the sternum[1].

[1] Although the Vienna specimen, above alluded to, shews that along with an undoubtedly imperfect first thoracic rib, the cartilage which meets the sternum at the junction of the manubrium and body may be that of the third thoracic rib, there are not wanting indications here that the first segment of the body has been ossified to the manubrium proper, which would explain the fact of the body supporting a cartilage too few and the manubrium one too many. Although it is not well shewn in the drawing, the edge of the sternum is not

Vertebra supporting the ribs. On examining a series of skeletons from behind and sideways, it is seen that the transverse processes of the 7th vertebra are more or less flattened, and are directed a little forwards and also a little downwards, the latter increased in appearance by the slope of the upper margin. In contrast with this, it is seen that the transverse processes of the 1st dorsal vertebra are directed backwards and also upwards, and are thick to their ends, and that their tips are wider apart than those of the 7th or 9th vertebrae. But these characters, in so far as they differ from those of the 7th, are adaptations to the support of ribs, and may be expected to vary accordingly. In the case under notice, the transverse processes of the vertebra supporting the rudimentary ribs are $\frac{1}{2}$ inch wider apart than those of the vertebra below, and are thick to their ends, but they are directed a little downwards and also a little forwards, while those of the vertebra below are directed much upwards and also backwards.

Muscles and arteries. The intercostal spaces were occupied in the usual way by the intercostal muscles and membrane. The scalenus anticus was attached, on each side, chiefly to the end of the rudimentary rib, partly to the ligament close to it, and a large tendinous slip passed down on the inside of the internal intercostal muscle to be fixed to the upper margin of the 2nd rib, which shews a slight roughness there. The subclavian vessels were normal in their relative anatomy. The artery lay immediately behind the scalenus upon the groove of the rib. As a line between the tips of the rudimentary ribs passes only $\frac{1}{8}$ inch in front of the body of the vertebra, the position of the subclavian artery must have been farther back than usual. A line drawn across between the subclavian grooves, at their

uniformly oblique, especially on the left side, but there is, first, a more outstanding part opposite the small first cartilage and part of that of the second rib, and below this, opposite most of the cartilage of the second rib, there is a notch similar to those which receive the cartilages on the body of the sternum. Opposite the lower part of this notch a faint elevation crosses the front of the sternum, smooth but quite as distinct as those between the notches for the 4th and 5th pairs of cartilages. On this supposition, the manubrium, in this case, would correspond exactly to the manubrium together with the first segment of the body of a robust sternum in my collection, in which the short manubrium is $1\frac{3}{4}$ inch, the first segment of the body $1\frac{1}{4}$, the division between them running across at the lower edge of the second cartilage, and there is almost no interval, on one side, between the outstanding part for the first cartilage and the oblique part for the second.

fore part, gives a rather variable distance in front of the bodies of the vertebrae in different skeletons, ½ to ¾ inch, or even 1 inch.

(b) VARIETIES OF THE STERNAL END OF THE RIBS; GREAT BREADTH AND BIFURCATION OF RIBS, BIFURCATION OF CARTILAGES, ENCLOSED SPACES. I have several specimens of these varieties, which may be of interest to the physician or to the surgeon.

1. *Fourth rib on both sides becoming broad, and bifurcated in front.* Male aged 93. From about the middle of the shaft these ribs begin gradually to increase in breadth from 7 lines to 1½ inch on the left side, 1¼ on the right. They then fork, the left 1¼ inch, the right ¼ inch from where they join their cartilages. Cartilage of right forks close to rib, enclosing a space which admits little finger. Cartilage or cartilages of left now lost, but the diverging bony divisions, each of good breadth for a rib (6 to 7 lines) enclose an intercostal space 1½ inch in length, attaining a breadth of ¾ inch, which was probably continued forwards by the divisions of the cartilage or by two cartilages. This condition might well give rise to mistake in indicating the position of a chest symptom or of a fracture. The cartilage of the 7th rib on the left side is double for 1½ inch, nearer the costal than the sternal end, the two portions, each about half an inch broad, separated only by a narrow space. All the other ribs and cartilages on this side, and all but the 4th on the right side, normal. The cartilages are becoming invested by plates of ossification.

2. *Left fourth rib becoming very broad, and bifurcated in front; two large spaces, one in the bone, one at the bifurcation.* The other ribs normal in form, and number of ribs normal. Age and sex unknown, but rib is robust. Rib before it begins to enlarge, behind middle, 8 lines in breadth, at beginning of fork 1½ inch. Before it forks there is an oval window, length 8 lines, height 4, admitting point of fore-finger; edges of this window thin and irregular, but rib between it and the fork, which occurs 8 lines farther on, is of the full thickness. The large oval window is 1 inch in length by 8 lines in height; ¾ of it between the bifurcated bone, the rest between the bifurcated and now ossifying costal cartilage.

3. *Left fourth rib becoming broad towards sternal end, where it joins bifurcated cartilage.* Female aged 19. Same subject as case No. 1 of rudimentary 12th rib. Breadth of rib at middle of shaft 7 lines, at front end 14 lines. Vertically oval window between end and bifurcated cartilage 6 lines by 3.

4. *Rib broad at sternal end, with bifurcated cartilage.* Robust right rib, closely resembling 4th rib of case 1, but an inch longer. Over 12 inches in length, and is probably the 4th or 5th rib. Breadth at middle of shaft 8 lines; at front end 16 lines. Window between end and bifurcated cartilage admits point of fore-finger.

5. *Bifurcated cartilage.* Anterior $\frac{2}{3}$ of a robust left rib. Curvature indicates it to be probably the 4th rib. Rib broader than usual in anterior two inches, but rather diminishes in breadth along upper margin in last inch, and along here is applied the upper division of a bifurcated cartilage, the other division, the larger, meeting the end of the rib. Window admits point of fore-finger.

In three of these cases the variety was ascertained to be of the 4th rib, another probably of the 4th, the other two probably either of the 4th or 5th. In three it occurs on the left side only, in one on the right, in one on both sides. One was in a female aged 19. There is no trace of fracture or injury on any of these specimens.

(c) VARIATION OF THE COSTAL FACETS ON THE 9th AND 10th DORSAL VERTEBRAE. The text-books of anatomy differ in regard to these facets. The following is the result of the examination of 21 sets of vertebrae, excluding those which present other variations. The points to be noticed are, whether the 9th presents an articular facet on its lower edge for the head of the 10th rib, and if not, whether the facet on the 10th is complete. Also whether the costo-transverse facet of the 10th vertebra is absent.

The ninth vertebra had the lower facet on the "body," on both sides in 3; on one side, but uncertain whether present on the other side, in 3 (2 right, 1 left); on one side only in 4 (3 right, 1 left). Uncertain on both sides 2; leaving 9, perhaps 11, of the 21 in which the ninth vertebra bears no facet below.

Among these 9 cases the body-facet on the 10th had the appearance of being "entire" in 5. Thus in 17 of the 21, the facet on the tenth was not complete, at least the fibro-cartilage being necessary to its completion; and in 10 of the 21, the ninth vertebra had a lower body-facet in at least 3 on both sides, and in 7 others certainly on one side. I do not here include those in which the lower edge of the 9th vertebra presents not only the usual slight elevation to which the upper band of the stellate ligament is attached, but also a triangular recess below and behind the elevation. That recess, although it may accommodate the head of the 10th rib in certain motions, is not articular in relation to the rib, in the sense in which the other demi-facets are. The prominence and recess behind it are seen on the 11th and 12th and upper lumbar vertebrae. The lower part-facet on the 9th is large in some, in others small but distinct. The head of the 10th rib generally presents a corresponding modification, having a somewhat rounded outline above, the upper angle being more or less rounded off. These observations refer to the characters presented by the bones.

In the above 21 sets of vertebrae, the *costo-transverse facet* of the 10th dorsal vertebra was wanting, on both sides in 4, on one side (1 right, 1 left) in 2; and its presence was uncertain in one case on one side, in another on both sides. In only one case the absence of the 10th costo-transverse facets was conjoined with the presence, though uncertain on one side, of the lower facet on the body of the 9th; in all the other cases of absence of the 10th transverse facet, the head of the rib was set low, in two of them the body-facet on the 10th being entire. The absence of the transverse facet is in some accompanied by the absence of the tubercle of the rib; in others the tubercle is moderately developed[1].

[1] *Among the cases presenting other variations*, the following was noted of these costal facets. In two cases of unequal 12th ribs (cases Nos. 3 and 4) the head of the 10th rib had an entire facet on the 10th vertebra; in one, the costo-transverse facet was wanting on both sides, in the other it was present on both sides. In case No. 8, lumbar variation (dorso-lumbar vertebra less than usual, and movable 12th rib on one side only), the head of the 10th rib did not touch the 9th vertebra and the 10th costo-transverse facets were wanting. In the five cases of additional dorso-lumbar vertebra (cases Nos. 3, 4, 5, 6, 7 lumbar variation) in all the head of the 10th rib articulated in part with the 9th vertebra, except on one side in case No. 6. In case No. 3 (13th pair of ribs also present) the costo-transverse facet was wanting on both sides

The costal facets on the 9th and 10th dorsal vertebrae, therefore, vary so much that they cannot be relied on as distinguishing characters of these vertebrae. If the 9th has the part-facet below, it resembles the 8th; if that facet is wanting, it resembles the 10th. Unless the 10th has the body-facet entire, it cannot be distinguished from a 9th; and as, along with an entire body-facet, it may want the transverse facet, it comes in these respects to resemble an 11th. In like manner the 11th resembles the last-mentioned variety of the 10th, or it may have the lower articular processes turned outwards, and be taken for a 12th. Again, the 12th may not have its lower articular processes turned outwards; and the 1st lumbar may have carried a rib. These varieties, however, of the two last dorsal and of the 1st lumbar are rare, compared with those of the 9th and 10th dorsal.

(d) IMPERFECT DEVELOPMENT OF 12TH RIB. Case 1. *Twelfth Ribs very small.* Female aged 19. Preparation of three dorsal vertebrae and first lumbar, with 11th and 12th ribs. Twelfth pair of ribs so small that they might easily have been overlooked. I ascertained carefully that these were the twelfth from above downwards, and there were five lumbar vertebrae below them. They are nearly symmetrical. Length of right 1 inch, of left a line less. Breadth at the middle, right $\frac{1}{8}$ inch, left $\frac{1}{6}$, each expanding a little at the end. Thickness of outer half under a line, of inner half nearly $\frac{1}{8}$ inch. Head rounded, and $\frac{1}{4}$ inch from it is a tubercle, where the rib also bends forwards, giving the appearance of a neck and tubercle. Head retained by capsular ligament, articulates with a facet on the upper and fore part of the pedicle near where it joins the body, and corresponding to where head of 11th rib joins its vertebra, although the 12th rib appears as if not so far back on the pedicle owing to its lesser size. Change of direction of articular processes takes place between 11th and 12th dorsal vertebrae. This modifies the character of the neighbourhood of the superior articular process of the 12th vertebra; metapophysis (superior tubercle, or mammillary process) moderately de-

on the 10th, but present on one side of the 11th vertebra. In case No. 4 (13th pair of ribs also present) the 10th costo-transverse facet was absent on one side, well marked on the other side.

veloped; anapophysis (inferior tubercle, or accessory process) very slight; no transverse process (external tubercle) present. Transverse process of 1st lumbar 5 lines in length, 3 in breadth, and springs as usual from the back part of the pedicle, with a slight anapophysis behind it. *Eleventh* ribs each 6 inches in length, and $\frac{1}{2}$ inch in breadth at middle, where they are broadest. Besides costo-vertebral articulation, they are connected to the external tubercle by a strong ligament. This case was published in 1853 along with the case of imperfect 1st thoracic rib above noted. It is one of the cases (No. 3 of that variety) in which the sternal end of the left 4th rib was broad, with bifurcated cartilage.

Case 2. *Same as the case just related.* Adolescent subject. Preparation shewing 7th cervical vertebra, 12 dorsal vertebrae with their ribs, and 3 lumbar vertebrae; a vascular preparation. Eleventh ribs 4 inches long, $4\frac{1}{2}$ with the cartilage. Rudimentary 12th rib, length of left 1 inch, of right $\frac{3}{4}$; breadth of each about $\frac{1}{3}$ inch. Inner end is set on anterior and upper part of pedicle of vertebra, the right by a short intervening process, corresponding to where the 11th rib is set upon its vertebra. Change of direction of articular processes of vertebrae takes place chiefly between 11th and 12th dorsal.

Case 3. *Twelfth Ribs short and unequal.* Female aged 40. Vertebrae, C. 7 (with rib on 7th; case No. 5 of cervical rib), D. 12, L. 5, S. 6, C. 3. Length of left 12th rib $1\frac{1}{6}$ inch, of right $1\frac{3}{4}$. Breadth of left 3 to 4 lines, right the same but much larger than left at its head. Head of right articulated on short blunt elevation on lower $\frac{2}{3}$ of side of pedicle, corresponding to where 11th rib rests on its vertebra, making allowance for the elevation pushing back the articulation of the 12th. A low tubercle or roughness external to the head, but without any interval, is in contact with a slightly developed transverse tubercle of the vertebra, but there is no facet. The fusion of the rib and vertebra would, at this part, represent the transverse process of the first lumbar vertebra. The shorter rib (left) rests on a narrow eminence below the middle of the pedicle, by a notched head, the part behind the notch not quite close to the slightly developed transverse tubercle behind it. Change of direction of articular

process has taken place partially between 11th and 12th vertebrae on left side, being the side of the smaller 12th rib. Tenth dorsal vertebra has an entire costo-capitular facet and a very large costo-transverse facet, although the transverse processes are short.

Case 4. *Very unequal 12th Ribs.* Male aged 47. Vertebrae, C. 7, D. 12, L. 5, S. 5, C. 4. Twelfth ribs of very unequal length, that of left 3½ inches, of right scarcely 2 inches. The larger one has a much larger and more distinct head, and a broader shaft than the other. The three tubercles on the transverse process of the 12th dorsal vertebra are very pronounced on both sides. The external of these is in series with the transverse processes of the lumbar vertebrae, but, as far as mere position and form go, if the transverse processes are looked at from above, the antero-posterior broadening at the root suggests a double relation, very distinct in this specimen, the posterior continuation corresponding to the external (transverse) tubercle of the 12th dorsal vertebra, the anterior to the 12th thoracic rib, this root of the process curving forwards on the pedicle. The head of the lesser (right) 12th rib is flat, rests on the upper half of the body of the vertebra, at the fore part of the pedicle, on a slight elevation. Behind, it has a cartilaginous facet on its lower part, an interosseous ligament at its upper part. The upper band of the stellate ligament went to the fibro-cartilage above. A strong costo-transverse ligament connected the rib to the external of the three tubercles on the transverse process, leaving a costo-vertebral space, or lateral foramen, between the two articulations. In connection with the shortness of the 12th rib on the right side may be noted the fact, that the transverse process of the 5th lumbar vertebra is ankylosed to the sacrum on that side. The 10th dorsal vertebra has an entire costo-capitular facet, and no costo-transverse facet although the transverse processes are well developed.

Case 5. *Twelfth Ribs short and ankylosed to Vertebra.* Female aged 62. Considerable lateral curvature of spine to left side, with articulation of left transverse process of 5th lumbar vertebra to sacrum. Vertebrae, C. 7, D. 12, L. 5, S. 5, C. united and obscure. All the other ribs normal. Length of eleventh

5½ inches. Twelfth ribs, right 1⅜, left 1⅛, breadth about ¼ inch. Left thick internally, tapering outwards, with a direction downwards (this being the side to which the spine is curved), and passing ½ inch farther out than the transverse process of the 1st lumbar vertebra. Right directed rather upwards and nearly parallel to the lumbar transverse process, and passing over ½ inch beyond it. Line of ankylosis quite visible on right side, just traceable on left. The heads have been implanted on short processes from the fore part of the pedicle, corresponding to where the 11th ribs rest on their vertebra. On right side, between the pedicle and the transverse tubercle of the vertebra behind, and the part of the rib representing its neck and tubercle in front, there is a narrow space; on the left side this is filled up by bone. These ankylosed ribs have a general resemblance to lumbar transverse processes, in at least their projecting portions, but inwardly they begin from the anterior instead of from the posterior part of the pedicle.

(e) VARIATION IN THE POSITION AT WHICH THE CHANGE FROM THE DORSAL TO THE LUMBAR DIRECTION OF THE ARTICULAR PROCESSES TAKES PLACE. This change normally occurs between the 12th dorsal and 1st lumbar vertebrae, and is not accomplished by an intermediate position of the two processes, but entirely by the process of the vertebra above assuming the lumbar type. This character, however, of the 12th dorsal vertebra is not invariable. The following ten cases are examples.

Cases 1 and 2. In the two first related cases of imperfectly developed 12th rib we have seen that the change takes place between the 11th and 12th dorsal vertebrae. In the first of these cases the change is complete and symmetrical, in fact the lower processes of the 11th look more decidedly outwards than those of the 12th and 1st lumbar. In the second case it is symmetrical but less complete, though more resembling the lumbar than the dorsal.

Case 3. In this case (yet to be noticed, case 8 of lumbar variation; vertebrae C. 7, D. 11 or 12, L. 5 or 4, S. 6, C. lost) the change takes place, and completely, with the lower pro-

cesses of the 11th dorsal. A slightly movable 12th rib exists on one side only.

Case 4. Female skeleton. Grouping of vertebrae normal. Articular processes change between 11th and 12th dorsal, on left side completely, on right side not completely, but more resembling lumbar than dorsal.

Case 5. In an otherwise normal spine (young, 20 inches in length) the change is not fully accomplished till between the 1st and 2nd lumbar vertebrae, the processes between the 12th dorsal and 1st lumbar partaking more of the dorsal than of the lumbar direction. Costal facets normal.

Case 6. In this robust adult spine, the change is only half accomplished between the 12th dorsal and 1st lumbar vertebrae, the direction of the processes being exactly intermediate. Costo-capitular facets on 12th vertebra well marked.

Case 7. The case to be described under lumbar variation, No. 1, presenting 13 ribs, contains an example of the change taking place chiefly a vertebra lower than usual.

Case 8. The skeleton in Dr Barclay's museum, having an additional dorso-lumbar vertebra and 13th rib, presents an example of the change taking place a vertebra lower than usual. This skeleton is noticed in foot-note to case No. 3 of lumbar variation.

Case 9. In another robust adult spine (C. 7, D. 12, L. 5) the change takes place between the 11th and 12th dorsal on one side, the left, but not on the other. Yet, as far as their direction is concerned, the processes of the space above and of the space below are symmetrical. But there has been some lateral curvature of the spine towards the right side, and the edges of the bodies throw out excrescences on that side. Costo-capitular facets on 12th dorsal vertebra well marked, the right the larger and deeper. Tenth dorsal vertebra has the costo-capitular facet entire on the right side, and no facets on its well-developed transverse processes. The transverse process of the 12th seems to develope a shorter metapophysis on the side on which the articular processes between it and the 11th have

changed to the lumbar type; but this necessarily follows; the change in the direction of the process filling up the space which otherwise separates the metapophysis and the superior articulating process.

Case 10. Adult male skeleton in the Anatomical Museum of the University. Ribs and grouping of vertebrae normal. The same want of symmetry is seen in this case as in the last, but between the 12th dorsal and 1st lumbar vertebrae. The articular processes of the left side retain the dorsal type, facing front and back, while those of the right side have assumed the lumbar type. The articular processes of the space above and of the space below are normal and symmetrical. Costal facets normal. Twelfth ribs 5 inches in length and symmetrical. There is no abnormal curvature or disease. The skeleton is a tall, robust, well-proportioned, and healthy one[1].

[1] *Articular Processes in Animals.* It is interesting to observe the various situations at which the change of direction of the articular processes takes place in different animals. My limits prevent me from going into this comparison more fully at present, but I may state generally that the change from the thoracic to the lumbar type of process takes place in most quadrupeds more or less in front of the last thoracic, leaving from 1, or more generally from 2, to as many as 5 of the dorsal vertebrae with articular processes of the lumbar type, these generally corresponding to where the ribs are small or less firmly articulated. Along with this, generally but not always, is seen the convergence of the spinous processes to the point where the change of the articular processes takes place, of which the feline back presents an exact and striking illustration. In others, again, of which the Indian Tapir is a striking example, the thoracic type commences in the lumbar region; in the tapir (Vertebrae C. 7, D. 18, L. 5) commencing as far back as between the two posterior lumbar vertebrae. In this animal all the spinous processes slope backwards, and all the ribs have the head intervertebrally placed, and all of them except the last have a costo-transverse articulation. But that the place of change is not regulated only by number of ribs and length of the ilio-costal space is seen, for instance, in the Kangaroo and Wombat, in both of which the place of change is between the 11th and 12th dorsal, leaving behind it, in the kangaroo 2 dorsal and 6 lumbar, in the wombat 4 dorsal and 3 or 4 lumbar and a short ilio-costal space. In most the change is sudden as in Man, but in some it is gradual, extending over two or even three spaces. The part to which the anterior spinous processes slope back and the posterior slope forwards is sometimes termed the centre of motion, and the vertebra to which they incline the "anticlinal" vertebra. The convergence of the spinous processes is no doubt the most striking feature, and the other processes change more or less here, but the change of the articular processes is the fundamental one.

The change from the cervical to the thoracic type of articular process is not so gradual as in man, but is generally abrupt and situated some way within the thorax; generally between the 1st and 2nd dorsal vertebrae, in some between the 2nd and 3rd; or it may be divided between the 1st and 2nd and the 2nd and 3rd, or between the 2nd and 3rd and the 3rd and 4th, but still strikingly visible. In man it is not easy to recognise the change from cervical to dorsal articular processes, at least from the oblique to the vertical, though the shifting of the processes inwards is evident below the 1st dorsal on comparing the lower with the upper processes of that vertebra.

(C.) Variations in the Lumbar Region.

(a) Lumbar Ribs. Case 1. *Lumbar Rib on both sides, but unequal, giving thirteen pairs of ribs.* Adult female. Preparation shews 7 cervical, 4 lumbar, and 13 vertebrae bearing ribs, and the parts bounding superior aperture of thorax. First thoracic rib incomplete on right side. *Thirteenth rib*, on right side, the larger, length almost 3 inches, average breadth 3 lines, at middle 4. On left side, length $1\frac{1}{4}$ inch; breadth at middle over 2 lines, expanded at outer end to 3 lines. Head of each rests on vertebra at upper and fore part of pedicle, upper part of head resting on parapophysial elevation, most marked for the smaller rib. Each has likewise a synovial costo-transverse articulation, a distinct facet on the rib articulating with the external tubercle which represents a rudiment of a transverse process, ligamentous fibres intervening between the two articulations. The lumbar ribs recede to this point and then turn outwards and forwards. Both 13th ribs slant downwards like the 12th ribs, in contrast with the transverse processes of the vertebra below, which are horizontal and about $\frac{1}{2}$ inch in length. Tip of shortest 13th rib projects nearly $\frac{1}{2}$ inch beyond tip of transverse process below it. *Twelfth ribs*, on right side $5\frac{1}{4}$ inches in length, breadth nearly $\frac{1}{2}$ inch at middle; on left side outer part now removed but it was, like the left 13th rib, shorter and more slender than its fellow. *Vertebrae.* Articular processes assume lumbar type a space lower than usual. The change is partially effected at the usual place on the right side, but on left side the processes still have strictly the direction of dorsal processes. Spine of 12th dorsal vertebra has sloping upper edge; spine of vertebra below it is square-shaped and nearly horizontal. *First thoracic rib*, on right side is imperfect. For

The study of the direction of the mammalian articular processes is much facilitated by beginning with an earlier type, as in the Crocodile. There all the processes—cervical, thoracic, lumbar, caudal—are on the same general and simple type. The anterior pair form the sides of a socket (zygantrum) facing inwards and more or less upwards, the posterior pair forming a wedge (zygosphene) fitting into the socket. It is now easy to see by what simple changes, in one or two directions, processes corresponding to those in the different regions of mammals may be obtained; those of the posterior regions having departed least, those of the thoracic region most, from the early type.

$\frac{3}{4}$ inch in front it is represented by a ligament which joins internally the narrow first costal cartilage, most of which is ossified, more so than the cartilage of the other side is. Shaft is slender, $2\frac{1}{2}$ inches in length, $\frac{1}{4}$ inch in breadth at the subclavian groove. This deficiency of 1st rib is on that side on which the 13th rib is longest. Transverse process of 7th cervical vertebra presents well-marked bifurcation, with small-sized foramen. Anterior transverse processes of atlas incomplete on both sides.

Case 2. *Lumbar Rib on both sides.* No history. Preparation of an otherwise characteristic robust 1st lumbar vertebra. Left rib the longest and thickest, length $2\frac{3}{4}$ inch, right $2\frac{1}{4}$. Both expanded at outer third to breadth of $\frac{1}{2}$ inch, thicker and a little narrower along inner $\frac{2}{3}$, right the more slender as well as the shorter. *Relation to the vertebra.* Each presents a terminal facet, articulating with a parapophysial elevation placed where the upper and fore part of the pedicle joins the body, and a posterior facet, close to the other, which articulates with a slight eminence on the lower and back part of the pedicle. On the left side, however, these two surfaces on the pedicle appear to have been continuous by a narrow connection. Back of rib external to this is in relation with the transverse process, which is $\frac{1}{2}$ inch in length, but with a narrow interval between. No facet here, but marks of ligamentous attachments. The parapophysial eminence, pedicle, and transverse process together form a somewhat square-shaped socket into which the elongated head of the rib is received, but without contact with the transverse process, and motion must have been limited. The elongated head of the rib gives the appearance as of a head and tubercle without a neck, but both the facets appear more strictly to belong to the head, the costo-transverse articulation having been ligamentous only[1].

[1] *Two cases of Lumbar Rib in the Ox; in one the rib placed on the end of the transverse process, in the other placed in the usual situation.* 1. The rib in this case, as in case No. 8 following in this series, is placed on the end of the transverse process, and on one side only, but it is a supernumerary rib and there is no serial variation of the vertebrae. Skeleton of a short-horn cow in the Anatomical Museum of the University. Vertebrae C. 7, D. 13, L. 6, the first carrying the rib. Transverse process of first lumbar vertebra $2\frac{1}{2}$ inches in length on right side. On *left* side a movable rib, 4 inches in length, is supported on a transverse process 6 inches in length. First inch of latter is like the root of the transverse processes; then follows an enlargement as if the

(b) More complex Lumbar Variations. Vertebrae and Ribs. Case 3. *A Dorso-lumbar Vertebra more than usual, with additional pair of Ribs.* Male aged 50. Preparation shews, cervical vertebrae 7, dorsal 12, lumbar 6, the first having lumbar ribs, sacral 5, coccygeal 3 or 4, probably 4. *Thirteenth ribs,* nearly symmetrical, but right a little longer and thicker than left. Right, length 2 inches; breadth of shaft at inner two-thirds, $\frac{1}{8}$ inch, at outer third $\frac{1}{4}$. Left, length $1\frac{7}{8}$, a little less in breadth that right. Both are thinner as well as more expanded at outer third than along inner two-thirds. They slope a little downwards, but direction not very fixed as they are freely movable. They reach out 1 inch beyond tips of transverse processes of vertebra below. The latter slope a very little downwards, are 1 inch in length, measured from the body, and $\frac{1}{2}$ inch in breadth. *Articulations.* Head surrounded by ligament. Also interosseous and costo-transverse ligaments, occupying all the length of the transverse process and outwards from it. Length of transverse process $\frac{1}{4}$ inch. Head rests by articular facet on parapophysial eminence situated where upper and fore part of pedicle joins body. As the dissection was not so fresh as I could have wished I could not satisfy myself whether at any part external to the head there was a second synovial membrane or only loose connective tissue, within the ligament, but there was no second cartilaginous facet. The motion of the rib, with the ligaments entire, was very free. *Twelfth rib,* length of right 7 inches; breadth along inner part of shaft 5 lines, outer part $\frac{1}{2}$ inch. Left now removed. Large cartilaginous facet for head, and same synovial cavity reaches out to end of transverse process, but there is no

rest of the process had been separate and become ankylosed here. This long transverse process is curved backwards like the 13th rib, and as broad as it, while the transverse process behind it, 4 inches in length, is curved with concavity forwards. As the movable rib and transverse process now present irregular bony ends, they have probably been united by cartilage. 2. Occurs in a Bos grunniens, on both sides. Vertebrae C. 7, D. 14, L. 5. The supernumerary (14th) rib is long and well formed; length along curve $10\frac{1}{2}$ inches, straight 9, being only $1\frac{1}{2}$ inches shorter than 13th rib. Shaft as broad as that of 13th along vertebral half, and nearly as broad as 13th along lower half. Head intervertebral. Costo-transverse articulation present on right side, none on left; present on 13th rib on both sides.

In this *Journal* for November 1871, I recorded a case in which I found a supernumerary (16th) pair of ribs in a Great Fin-Whale (Balaenoptera Musculus). In this case the supernumerary ribs floated among the muscles, unconnected with the vertebrae.

external facet. Same on both sides. Transverse process, as on vertebra supporting lumbar ribs, ¼ inch in length; metapophysis and anapophysis also well marked on both. *Eleventh rib,* costo-transverse facet present on right side, ½ inch out from the head; none on left side. *Tenth rib,* no costo-transverse facet on either side; head rests partly on 9th vertebra on both sides.

Sixth lumbar vertebra. (25th vertebra.) Freely movable. Has the characters of a normal last lumbar vertebra, including normal transverse processes. Lower articular processes ¼ inch wider apart than upper, but are not wide apart (1⅝ inch), and look very much inwards. Lower processes of fifth also ¼ inch wider apart than upper. Antero-posterior thickness of pedicles, 9 lines; those of fifth, 7 to 8 lines; those of fourth, 4 to 5 lines. Lumbo-sacral fibro-cartilage same length at middle as those above, but less at the sides. Distance between transverse processes and sacrum nearly ¼ inch. Two entire nerves, being the 5th and a 6th lumbar, went down to join the sacral plexus. The obturator arose from the 3rd and 4th, the anterior crural from the 2nd, 3rd, and 4th. *Sacrum.* The 5 pieces completely ossified together. Greatest breadth 4½ inches; length at anterior surface, straight 3¼ inches, along curve 4¼; depth of curve 1¼. Promontory well marked. Upper surface of wings a little more sloping than usual. Auricular surface extends down to nearly opposite lower edge of 2nd foramen. Canal opens at 3rd space. Horns short, outer boundary of 4th foramen ½ inch broad. Lower end, breadth 9 lines; less motion here than between 1st and 2nd pieces of coccyx. *Coccyx,* in three movable pieces, the third apparently composed of two. Total length 1½ inch. First piece, length 6 lines; breadth including short transverse processes, 15 lines; very short horns, connected to sacral horns by ligament. Second piece, length 4 lines, breadth 8 lines. United third and fourth pieces, length 7 lines, of which 4 belong to third; line of ankylosis indicated by deep notch at either side, by a furrow in front, and by a deep fissure behind going more than half through the thickness of the bone. Third piece diminishes in breadth from 6 lines to 4. Fourth piece, breadth at first 5 lines, semilunar termination. After comparison with other specimens of more or less ankylosed coccyx it must be concluded that this coccyx has had four pieces.

We have, therefore, in this case an instance of an additional lumbar vertebra, with an additional pair of ribs, together with the full number of sacral and, apparently also, of post-sacral vertebrae[1].

Case 4. *A Dorso-lumbar Vertebra more than usual, with additional pair of Ribs; the sixth lumbar vertebra partly united to the sacrum.* Male aged 29. Preparation shews entire spine with vertebral ends of ribs, the vertebrae still united by their fibro-cartilages. Vertebrae, cervical 7; dorsal 12; lumbar 6, the first carrying ribs, the sixth partially united to the sacrum; sacrum 5, exclusive of sixth lumbar; coccyx 4, first separate,

[1] *Case of additional dorso-lumbar vertebra and additional rib in Dr Barclay's Museum.* I was acquainted with a skeleton in the Barclay Collection in the Edinburgh College of Surgeons, marked "Skeleton of a European male used by Dr Barclay in his lecture-room, as having thirteen dorsal vertebrae and thirteen ribs on the left side." My notes of it contain the following. Vertebrae C. 7, D. 13, L. 5, S. and C. ankylosed together. Seven well-formed cervical vertebrae. The seven upper ribs join sternum in usual manner. Twelfth rib over 6 inches in length along the curve, and same on both sides. *Thirteenth rib*, length $1\frac{7}{8}$ inch, breadth $\frac{1}{8}$ inch. Head rests on a short parapophysial elevation, and a short transverse process is in close relation with the rib posteriorly. Appearances indicate that a corresponding supernumerary rib has been present on right side also, but probably not so much developed. Lower articular processes of 12th dorsal do not undergo the change to the lumbar type, those of 13th the first to do so, but the processes between the 12th and 13th are smaller than those higher up and are not quite symmetrical. Lower articular processes of 4th lumbar (24th vertebra) $1\frac{3}{8}$ inch apart, and only $\frac{1}{8}$ inch wider apart than its upper processes. Lower processes of 5th lumbar 2 inches apart, and about $\frac{1}{2}$ inch wider apart than its upper processes. Sacrum and coccyx ankylosed in one piece; 5 pairs of foramina and an irregular mass beyond. Uncertain whether this mass comprises 2 or 3 pieces. Coccyx twisted to right side, making 4th and 5th foramina much smaller on right than on left side. Canal of sacrum opens opposite upper edge of 5th foramen. Sacro-iliac articulation reaches down to midway between 2nd and 3rd anterior sacral foramina.

We have in this case an instance of a dorso-lumbar vertebra more than usual, with additional rib; but as it is uncertain whether the sacro-coccygeal vertebrae have been 9 or only 8 in number, it is uncertain whether there has been also an absolute addition to the number of the vertebrae.

Case of additional dorso-lumbar vertebra, with additional pair of ribs, in a Cat. This variation is seen in the skeleton of an adult cat in my possession. The vertebrae and ribs are still connected by their fibro-cartilages and ligaments. Vertebrae, C. 7, D. 13 or 14, L. 7 or 6. Change of articular processes from dorsal to lumbar between 11th and 12th dorsal, as usual. Supernumerary rib (14th), like the two in front of it, rests on body of vertebra only. Is $1\frac{1}{2}$ inch in length on right, 1 inch on left side, the latter just half the length of the 13th rib; and seems to have ended as a free floating rib. In the place of its attachment to the body of the vertebra, it is serial with the rib in front of it and with the transverse process behind it. The latter process is a little shorter than those behind it, but resembles them in direction and in springing from, in the developed skeleton, the side of the body of the vertebra. The seven lumbar vertebrae have the usual characters; and the sacrum its usual three vertebrae, ankylosed above and below.

three last ankylosed to each other. *Lumbar ribs* nearly symmetrical, but tip of left has been sawn off. Length of right 1½ inch, projecting ¾ inch farther than tip of transverse process of vertebra below it. Breadth 3 to 4 lines, a little broader and thinner at outer fourth. Transverse process below has same breadth but is thinner. Rib and process below both directed horizontally. *Relation to vertebra.* Same on both sides. Head forms triangular enlargement which is received into a kind of socket, formed, behind by the short transverse process, internally by a parapophysial elevation. Latter crosses pedicle obliquely downwards and backwards, presenting a partially divided but continuous cartilaginous surface, ½ inch in length, ¼ inch in breadth, on which end of rib articulates. The posterior surface, meeting this nearly at a right angle, is in close relation with the transverse process, which is ¼ inch in length, but there is no articular facet between them. Only up and down motion could occur here, and it cannot have been free. *Dorsal vertebrae.* No articular facet on transverse process of 10th on left side, but well marked on right; head of 10th rib touches 9th as much as 10th body, on both sides, although head of this rib on right side is exceptionally narrow.

Fifth lumbar vertebra. Transverse process has the usual upward slope and triangular form, but is much less robust than usual for the fifth as seen in front. Seen from above, there is that antero-posterior thickness of the pedicle which belongs to a normal 5th lumbar. *Sixth lumbar vertebra* (25th vertebra). Relation to sacrum—Fibro-cartilage in front is half the thickness of those above, narrow at the sides, becoming encrusted with ossification behind. Articular processes free; lower ½ inch nearer each other than the upper are, in contrast with those of 5th, which are ¼ inch wider apart than its upper processes. Distance between upper processes of sixth, 2¼ inch, at outer edges. Transverse process, on right side, massive, bluntly bifid; 8 lines in height at foramen, expanding outwards to form a wing 14 lines in height; articulates below with a concave surface on outer and back part of sacrum, ½ inch broad, forming outer boundary of a lumbo-sacral foramen. On left side transverse process larger, expanding into a wing 16 lines in height, and similarly bifurcated; line of articulation with sacrum, 1 inch in

breadth, and undergoing ankylosis. The line of suture is uneven, the approach being mainly by the descent of the transverse process behind and internally, and mainly by the ascent of the sacrum in front and externally. Foramen 5 lines across on this side, 7 lines on right; neither of them so large as 1st and 2nd sacral foramina, but fully as large as 3rd. Besides the nerve which occupied this foramen, the whole of the 5th nerve and part of the 4th passed down to the sacral plexus. *Sacrum*—5 pieces. Apart from the above-mentioned transverse process relations, it would pass for a well-formed though small-sized sacrum. Greatest breadth 4¼ inches, length in front 3⅜ straight, along curve 4; greatest depth of curve 1⅛. Upper surface of wing less sloping than usual on right side, more than usual on left side. Sixth lumbar vertebra is in line with the lumbar curve, and away back from the general curve of the sacrum. Auricular surface reaches down fully to opposite middle of 2nd foramen. Portion of sacrum has extended up so as to come in between lower part of left transverse process of sixth lumbar vertebra and ilium, but a small part of right has articulated with ilium continuously with where it articulates with sacrum. Canal opens at 3rd segment. No horns towards coccyx. Outer boundary of 4th foramen ⅓ inch in breadth. Lower end, 8 lines transversely. *Coccyx.* Total length 1⅛ inch. Four pieces. First piece separate, length over 4 lines, breadth, including transverse processes, 14 lines; horns very short. Last three pieces ankylosed; indicated by constrictions, marked enough in front, very distinct behind. Second piece, length under 4 lines, breadth 6 lines, tapering to 4. Third piece, length 3, breadth 4. Fourth piece, length between 2 and 3 lines, breadth 5.

We have in this case another instance of an additional lumbar vertebra, and an additional pair of ribs, together with the full number of sacral and post-sacral vertebrae. Or, if the 6th lumbar be regarded as the 1st sacral only partially consolidated, we have then a case presenting that condition, together with an additional pelvic vertebra, and a 13th pair of ribs.

Case 5. *Six Lumbar Vertebrae.* Male aged 56. Vertebrae C. 7, D. 12, L. 6, S. 5, C. 3. Dorsal vertebrae and ribs normal. Twelfth rib 5½ inches in length. *First lumbar vertebra* normal

except that it has no vestige of transverse process on either side, although there is a fair metapophysis and anapophysis. From this, and the presence of markings on the fore part of the pedicle, I am inclined to infer that there have been small lumbar ribs here, though they were not noticed in dissection. The appearances here are precisely like those on the corresponding parts of the 12th dorsal vertebra in case No. 1 of undeveloped 12th thoracic rib, supposing the minute rib to have been removed here. I have an otherwise normal spine in which the first lumbar vertebra shews this condition on the right side; with an ordinarily developed first lumbar transverse process on the left, there is, on the corresponding part on the right side, an irregular concave facet as if a movable process had been attached there.

Sixth lumbar vertebra. Is quite separate from sacrum. Lower articular processes $\frac{1}{10}$ inch less apart than upper. Distance between upper, $2\frac{1}{6}$ inches. Lower of fifth $\frac{1}{4}$ inch wider apart than upper. Transverse processes are more robust than usual; while those of the vertebra next above it are unusually short and narrow externally, with moderate increase of thickness at pedicle. Left process, length from body 1 inch, height 6 lines, thickness 4 to 5 lines. Right same length, commencing to bifurcate, giving height of $\frac{3}{4}$ inch, and is also thicker than left. These are not in contact with sacrum, but by bending to either side they are made to touch; articular facets are seen below their ends, and corresponding facets on the sacrum and partly on the ilium, just above the end of the sacro-iliac articular surface. On the left side these are small and form separate joints. On right side the articulation is for $\frac{1}{3}$ inch with a concave facet on outer and back part of sacrum, and, externally and continuously, with a flat facet of the same size on the ilium. Although the latter now appears separated by a rough furrow from the sacro-iliac joint, it was noted in the dissection that they were continuous. Sacro-iliac articular surface goes down to opposite a little below lower edge of 2nd foramen on left side, to below middle of foramen on right side. A rather scattered sacro-lumbar ligament passed up to the transverse process, and an ilio-lumbar ligament passed in to the transverse process of the 6th, none to that of the 5th, which is unusually short and

narrow. Thickness of fibro-cartilage, at middle, between sacrum and 6th vertebra nearly $\frac{1}{2}$ inch. Both 5th and 6th nerves went entirely down to the pelvis, the 5th a smaller nerve than it usually is. Obturator arose as usual from 3rd and 4th. Abdominal aorta divided as usual at the lower part of the 4th lumbar vertebra.

Sacrum. The 5 pieces quite ankylosed. Breadth $4\frac{1}{4}$ inches; length in front $3\frac{1}{8}$ straight, along curve $4\frac{1}{8}$. Greatest depth of curve $1\frac{1}{4}$. Promontory sharp. Upper surface of wings not more sloping than usual, if so much. Canal opens at 4th segment. Outer boundary of 4th foramen broad, $\frac{1}{3}$ inch on left, $\frac{1}{2}$ inch on right side. Horns short and unequal. Lower end, $\frac{1}{2}$ inch in breadth. *Coccyx*, of 3 pieces, ankylosed to each other. Total length 1 inch behind, $\frac{1}{8}$ less in front. First piece, length nearly 4 lines in front, 5 behind; breadth 11 lines; transverse processes very unsymmetrical, right narrow, left thick and robust, giving coccyx an obliquity to right side. Horns very short. Second piece, length 4 lines, breadth 7 lines. Third piece, length 3, breadth 6 lines. Ankylosis of 1st and 2nd the more complete, and much resembles that between 3rd and supposed 4th in case No. 3.

This case is an example of an additional lumbar vertebra, gained from the sacrum, the sacrum being compensated by borrowing one from the coccyx.

Case 6. *Six Lumbar Vertebrae.* Preparation shews the vertebrae and vertebral ends of ribs still united by their fibro-cartilages, upper 6 cervical removed, 4th coccygeal lost. From the size I infer that it is from a female subject. Vertebrae, dorsal 12, lumbar 6, sacral 4, coccygeal 4. Dorsal vertebrae normal. Transverse processes of 1st lumbar $\frac{1}{3}$ inch in length behind; those of 5th much narrower than those of 3rd and 4th, but have the usual upward slope and greater obliquity of lower margin, and moderate antero-posterior increase at the pedicle. *Sixth lumbar vertebra.* Transverse processes thick, 1 inch in length from the body; height on left side $\frac{3}{4}$ inch, on right 1 inch with commencing bifurcation. The right by its lower and outer part articulates by a synovial joint, below with the sacrum for $\frac{1}{4}$ inch, and outwardly for a like distance with the ilium, the

two joints being continuous. This is just above the upper end of the sacro-iliac joint, with which the lumbar process articulations appear to have been continuous. On the left side there is a space of $\frac{1}{6}$ inch between the process and the sacrum, and apparently no facets. Iliac articular surface on sacrum reaches down on right side to opposite middle of 2nd foramen, on left side to opposite lower boundary of foramen. Lower and upper articular processes of sixth equidistant. Lower of fifth, $\frac{1}{10}$ inch wider apart than upper. Distance between upper of sixth, $1\frac{3}{4}$ inch. *Sacrum* 4 pieces, fully ankylosed. Breadth $4\frac{1}{4}$ inches, length in front, straight 3, along curve $3\frac{5}{8}$; greatest depth of curve 10 lines. Canal opens at 4th piece. Promontory well marked, upper surface of wings less sloping than usual. Horns well developed. Lower end, a little expanded laterally, breadth 1 inch, sharp-edged and nearly flat. Fourth foramen a wide notch which lateral processes of first piece of coccyx would complete into a foramen if prolonged for $\frac{1}{4}$ inch on left, for $\frac{1}{2}$ inch on right side. Second sacral foramen fully larger than 1st, although it is here the foramen of the third nerve. *Coccyx.* Pieces still separate. First piece, length 8 lines, breadth between tips of wings $1\frac{5}{8}$ inch, each lateral process 4 lines at upper margin. Breadth of upper articular surface 1 inch; lower end $\frac{1}{2}$ inch in breadth and bevelled like normal lower end of sacrum, and motion more free here than between this vertebra and the sacrum. Its characters are thus transitional between 5th sacral and 1st coccygeal, but serially it is the 1st coccygeal (30th vertebra) and it is movable on the sacrum. Second piece, length 6 lines, breadth 9 lines tapering to 5. Third piece, length 4 lines, breadth 6 lines tapering to 3. Fourth piece was hanging loose and has now been lost; cartilaginous surface visible on which it rested.

This case presents an instance of an additional lumbar vertebra, obtained from the sacrum, while the sacrum has not borrowed a compensatory piece from the coccyx.

Case 7. *Six Lumbar Vertebrae.* A spine in the Anatomical Museum of the University; no history. Vertebrae C. 7, D. 12, L. 6, S. 5, C. lost. Dorsal and upper lumbar vertebrae normal. Marked increase of thickness of pedicle of 5th lumbar. *Sixth*

lumbar. Transverse processes thick, about as thick as little finger, and slanting very obliquely upwards. Right has short bifurcation, upper division narrow, lower close to sacrum with corresponding rounded facets ½ inch in diameter. Process is ½ inch short of reaching out to level of sacro-iliac joint. Left thick, instead of bifurcating, and is quite close to sacrum for ½ inch, with a facet. Included lumbo-sacral foramina elliptical and very oblique upwards and outwards. Articular processes not wide apart. Distance between upper processes of sixth, less than 1½ inch. Lower processes ¼ inch wider apart, directed nearly straight forwards, and not quite symmetrical. Lower processes of fifth are ⅛ inch wider apart than upper. *Sacrum* 5 pieces. Breadth 4⅜; length in front, straight 3⅝, along curve 3⅞; depth of curve 7 lines. This is a remarkably flat sacrum; the slight curve is where the 4th and 5th pieces join. Promontory well enough marked; upper surface of wings more sloping than usual at back part only, brim-line being well formed. Sacro-iliac articular surfaces appear to stop even before reaching to opposite upper edge of 2nd foramen, a sharp and prominent ridge here cutting them off from a doubtfully articular excavated surface which is continued ¾ inch farther, to opposite lower edge of 2nd foramen. Canal opens at 4th piece. Upper two pairs and lower two pairs of foramina of usual size. Lower end ½ inch transversely. No horns towards coccyx. Coccyx lost.

This case presents an instance of a sixth lumbar vertebra, obtained from the sacrum, while the sacrum is numerically compensated by borrowing a vertebra from the coccyx.

Case 8. *A Dorsal or Lumbar Vertebra less than usual; Eleven pairs of ribs; 12th dorsal, or 1st lumbar, vertebra with movable transverse process on one side.* Robust spine with vertebral ends of ribs, the vertebrae still united by their fibro-cartilages. Vertebrae C. 7, D. 11 or 12, L. 5 or 4, S. 6, C. lost. Tenth ribs do not touch 9th vertebra, and have no costo-transverse facet. Vertebral part of 11th ribs preserved for 2 inches, robust, left more so than right. *Eleventh dorsal vertebra.* Lower articular processes assume lumbar type (as already noted, case 3 of that variation). Metapophysis long and projecting

but would be more so on vertebra below but for the filling up implied in the change of the articular process. Transverse process a conical tubercle ¼ inch long on left side, still shorter on right. Heads of 11th and also of 10th ribs rest on the pedicles, in sockets the fore part of which is formed by a parapophysial elevation situated where upper part of pedicle joins body. *Twelfth dorsal or 1st lumbar vertebra,* presents on left side a transverse process which resembles that of vertebra below in its place of origin and its upward slope, but is longer than it by ⅛ inch (length from the body 1¼), and nearly a third broader (breadth ½ inch); and is also thicker, so that its base extends farther forwards on the pedicle than that of the process below, or than that of an ordinary first lumbar transverse process. On the *right* side, the corresponding part is in two pieces. Inner portion, ½ inch in length, is thick, rising from nearly the whole of the pedicle. It is thicker antero-posteriorly than the base of the left process, reaching especially more forwards on the pedicle. Articulated on the end of this long parapophysial eminence is a movable process 1 inch in length, its form and proportions extremely like those of the entire lumbar transverse processes below it, or of any ordinary lumbar transverse process. The intervening articular surface, as now seen, 8 lines in length backwards and downwards, 4 lines in breadth, most of it smooth and covered by cartilage, and undulating so that the motion must have been only up and down and very limited. This apparently has been an instance of what is termed development of the first lumbar transverse process from a separate centre. There is no reliable trace of ankylosis having taken place between two similar parts on the left side. Lowest lumbar vertebra (23rd vertebra) presents the usual characters of a normal 5th lumbar. Lower articular processes ½ inch wider apart than the upper. Distance between the upper, 1⅞ inch. Pedicles present the usual increased thickness of those of a lowest lumbar vertebra.

Sacrum, 6 pieces. The unusual shape of the 1st piece, and the dorso-lumbar vertebra less, lead to the inference that the extra piece has been borrowed from above. Breadth of 1st piece 4⅞ inch, of 2nd piece an inch less; length in front, 5⅛ straight, along curve 5⅝, without 6th piece 8 lines less; depth of

curve 1 inch. Curve is gained on lower 2 pieces, the general appearance of the front being that of great flatness. Body of first piece, instead of prolonging general curve of sacrum, lies back towards lowest lumbar vertebra, which it meets at a very obtuse angle, forming but a slightly projecting promontory. Upper surface of wings slopes downwards and outwards, but more especially forwards, forming a very obtuse angle with front of sacrum. Thickness of neck of 1st piece, opposite the foramen, is really less than that of 2nd piece (9 lines) as seen from before and below; but as seen from above, the 1st piece appears much the thicker of the two, owing to the obliquity. Auricular surface reaches down to opposite upper edge of 3rd foramen; angle is on first piece; upper part goes off at a very obtuse angle and is rather short, reaching on the anterior and lower half of the wing. Brim-line on first piece, runs from angle of auricular surface inwards and upwards to upper edge of first foramen, where it is lost. What the transverse mass of this 1st sacral vertebra wants, is that thickness of the fore part which normally carries the anterior surface of the sacrum so high above the 1st foramen as to give nearly a right angle with the upper surface, the rounded-off angle forming the brim of the true pelvis. But in this specimen there is but one surface, sloping from the upper boundary of the foramen to the upper border of the wing, almost in line with the front of the transverse processes of the lumbar vertebrae. This is the part occupied by the sacral rib in development, and as this vertebra is serially the 5th lumbar (24th vertebra) the absence of this element in its development would be sufficient to account for this peculiar form. The first three foramina are large, the 2nd less than the 1st and 3rd. Canal opens at 4th piece. No distal horns. Outer boundary of 5th foramen $\frac{1}{3}$ inch broad on left side; on right, foramen only half enclosed from below. Lower end nearly 7 lines transversely. Coccyx removed.

This case presents an instance of deficiency of a dorso-lumbar vertebra, accompanied by a variety in which the 12th rib and transverse process are convertible; and in which the seemingly absent vertebra has been united to the sacrum.

Case 9. *Six Cervical Vertebrae, and six Lumbar Vertebrae;*

and a Vertebra suppressed in some part of the column. Female aged 40. This case presents variation of several regions of the spine, but will be most conveniently noticed here. It might be defined simply as a spine on which the thorax is planted a vertebra higher than usual; but the first rib on one side has the characters of a half-developed supernumerary cervical rib; the articular processes change in the usual space, between the 19th and 20th vertebrae; two entire lumbar nerves went down from the lumbar region to the sacral plexus; and, while the sacrum has 5, the coccyx has only 3 pieces. As it actually stands, the grouping is, C. 6, D. 12, L. 6, S. 5, C. 3. The preparation presents the entire spine with the vertebral end of the ribs.

Sixth cervical vertebra. Anterior transverse process much less robust, especially on left side, than that of 5th. Lateral foramen double, anterior the smaller on left side; artery has not entered till 5th on left side (see case No. 16 of variation of lateral foramina in neck). *Seventh vertebra* (supporting 1st pair of ribs). Transverse processes directed a little downwards and nearly straight outwards, while those of vertebra below are slanted upwards and backwards; robust, but not so much so as those of vertebra below; long, between tips $2\frac{3}{4}$ inch, being a line more than in vertebra below. The inward shifting of the articular process, from cervical to dorsal, is, as usual, most marked below the 8th vertebra, very little between 7th and 8th.

First pair of ribs. Left, small, ceasing at middle of shaft. Head rests on upper part of body; right, broad, on a parapophysial eminence; left, narrow, sunk in a depression. Good costo-transverse articulation; head neck and tubercle 13 lines, right like an ordinary first thoracic rib, left narrower. Shaft of right has been sawn across after $1\frac{1}{2}$ inch, is rather narrower than ordinary first rib in female; breadth at subclavian groove 5 lines, at low scalene tubercle in front of this, 7 lines; groove for artery broad and moderately marked. Shaft of left, length $1\frac{5}{8}$, breadth at middle $\frac{1}{4}$ inch, tapers to subclavian groove, which is well marked, and in front of this forms flat terminal expansion, 5 lines in breadth. Inner part of this expansion is a muscular ridge, the lower aspect articulates with conical process of 2nd rib, and, anteriorly, an uneven surface is seen which has evidently given attachment to a small cartilage, or to a ligament,

prolonging the rib. Conical process of 2nd rib, ¼ inch in height, top truncated, forming flat oval facet, ⅛ inch in length, on which end of 1st rib rests by a now irregular surface. Intercostal space, length, from costo-transverse articulation to conical process, 1½ inch, and ½ inch in height at middle. On left side, 1st rib thus presents all the characters of a half-developed supernumerary rib, as in case No. 9, and on right side of case No. 10, of that variety. I have no note respecting the anterior part of the right first rib, the parts having been removed, but it has all the appearance of a rib which would reach the sternum. Head of 2nd rib has probably touched the 7th vertebra, at least on left side. The 3 lowest ribs have the same relation to their vertebrae which the normally placed 3 lowest have to their vertebrae. Head of 12th ribs, and the 1½ inch of their shaft which the saw has left, are of good size.

First lumbar vertebra (the 19th vertebra) has the ordinary transverse processes of an uppermost lumbar vertebra; length 5 lines behind, and ¾ inch along lower edge from body; about ¼ inch in breadth; and they spring from behind middle of pedicle. Direction horizontal. Metapophyses project, as they also do on the vertebra in front, the change of the articular processes not having taken place. Spine horizontal and quadrangular, spine next above it having sloping upper edge. *Next lowest lumbar vertebra.* Transverse processes have triangular form and upward slope, but in less degree, which those of lowest lumbar vertebra usually present; narrower and a little shorter than those next above; pedicle thicker than usual for a next lowest lumbar vertebra. Lower articular processes nearly ½ inch wider apart than superior. *Sixth lumbar vertebra* (24th vertebra). Transverse processes same length as those of 3rd and 4th; thick both ways, vertically ½ inch thick, antero-posteriorly right 9, left 7 lines. Slant a little upwards; outer ends bluntly oblique, facing to sacrum but ¼ inch from it: pedicle has the usual thickness of a lowest lumbar vertebra. Lower articular processes ⅛ inch less apart than the upper are. Distance between upper sixth 1⅞ inch.

Sacrum 5 pieces. Breadth 4¼ inch, length in front, 3¾ straight, along curve 4⅛, depth of curve 8 lines, curve mainly at lower half, beginning at middle of 3rd piece. Upper surface of

wings less sloping than usual. Auricular surface reaches on right side to opposite middle, on left side to near lower edge, of 2nd foramen; upper part of that surface broader on right than on left side. Canal opens at 4th piece. No horn on left, short on right side. Outer boundary of 4th foramen $\frac{1}{3}$ inch broad on right side, on left mostly wanting. Lower end, $\frac{1}{2}$ inch transversely. *Coccyx* represented by the three nodular pieces, ankylosed together. Total length $\frac{7}{8}$ inch in front, behind $\frac{1}{8}$ inch more. First piece, length 4 to 5 lines, breadth 6 lines, tapering to 5; presents slight depressions on each side on a front view, but no line across, and no mark of any kind behind. Second piece, length 3 lines, breadth $5\frac{1}{2}$ lines, widest at middle. Third piece, length nearly 3 lines, breadth $4\frac{1}{2}$, termination semilunar.

The variation in this case presents some complexity. To which region is the suppression of the vertebra to be referred? The lumbo-sacral nerves would seem to indicate that the lowest lumbar vertebra is the usual 1st sacral set free, thus accounting for the seemingly deficient pelvic vertebra, and leaving 23 instead of 24 vertebrae above. The appearance of suppression of a vertebra in the neck, is met by the consideration that the 7th vertebra carries ribs, imperfectly developed on one side, like cervical ribs. Then, although only 11 ribs remain, the next vertebra below, though rib-less, has the normal articular processes of a 12th dorsal (19th vertebra). If it is to be regarded as such, and not as the 1st lumbar, then the suppressed vertebra would be really a lumbar, although there are six free vertebrae between the thorax and the pelvis. Whichever view be taken, this case is an interesting one, as exhibiting variation in every region of the spine, and as shewing the importance of examining the entire spine before deciding as to a variation of any one part of it. The observation of the grouping of the nerves along the whole spine, would always be important in these cases, but the dissection is generally far advanced before the variation of the vertebrae is noticed.

(c.) VARIATIONS OF THE 5th LUMBAR VERTEBRA. (1) *Examination of Cases illustrating the changes by which it becomes united to the Sacrum.* This union is by ossification at the parts which attach the inter-transverse (sacro-lumbar) ligament. The

characters of the transverse process of the 5th lumbar vertebra which at once strike the eye, are, its greater thickness, tapering form, and upward slope. But a more remarkable character is the great antero-posterior thickness at its root, seen in a vertical view, making it appear to spring from the body as well as from the pedicle, as if a short rib had been consolidated here. The lumbar pedicles increase in thickness, antero-posteriorly, from above downwards, but that of the 5th is suddenly increased to about double that of the 4th. Beginning a little farther outwards at the canal, its attachment reaches obliquely forwards to near the middle of the side of the body, it may be even in front of the middle. This character is most conveniently referred to as increased thickness of the pedicle. The obliquity of the transverse process, as seen in front, is mainly on the lower edge, corresponding more or less to the similar slant of the neighbouring part of the sacrum. This margin presents, first, a concave part, the boundary of the intervertebral foramen, having generally a distinctly marked outer termination. Here the sacro-lumbar ligament begins, forming the outer boundary of the foramen. The outer more sloping part of the lower edge of the process is devoted to this ligament, the farther part of it, and also the tip, attaching the ilio-lumbar ligament. The lumbo-sacral ligament is attached, below, to the back part (transverse process part) of the wing of the sacrum; either to the developed upper angle and inwards from it, or, more inwardly, to the low conical process in which the back part of the wing may stop short. The distance between the transverse process and the sacrum varies a good deal; it is often $\frac{1}{4}$ inch, sometimes more, oftener less, often enough they are very near. They are brought together by lateral motion to that side and by extension, the ligaments of the opposite transverse process checking.

Specimens before me shew the process of sacralisation in various stages. In a female pelvis (case No. 8, sacral variation) the conical process (ascending inter-transverse process) rises up from the sacrum, so as to be almost in contact with the transverse process of the vertebra. In a male pelvis, aged 48, (case No. 9 of sacral variation) the sloping part of the transverse process is thickened downwards, and is within $\frac{1}{10}$ inch of the sacrum, for a breadth of $\frac{1}{2}$ to $\frac{3}{4}$ inch. In more advanced stages,

the transverse process acquires much greater thickness, and bifurcates, the lower limb of the fork (descending inter-transverse process), passes downwards and outwards towards the sacrum, and articulates movably with the sacrum below, and, it may be, with the ilium externally. In a farther stage, the union may be broad and sutural; and, finally, osseous union takes place.

In the four cases to be related in which this vertebra appears to have been included in the sacrum (cases 1 to 4, sacral variation) the union is symmetrical, and the variation has probably been congenital. In the specimens before me, in which the vertebra has probably been at one time more normal, the approach, or union, is very unsymmetrical, or occurs on one side only. This condition is probably related to a lateral inclination of the spine.

1. Female aged 62 (case No. 5 of Thoracic variation. Ankylosed 12th ribs). *Left* transverse process massive and bifurcated, descending division articulating with sacrum. Height of process, at middle, 10 lines; each division as large as middle-sized finger; upper attached the ilio-lumbar ligament; lower articulates, below, for $\frac{3}{4}$ inch, by a synovial joint, with a concavity on outer part of sacrum, which has ascended a little to meet it. Lumbar process, together with the elevated part of sacrum, is received into a depression in the ilium, close above auricular surface, but the union is only ligamentous. Motion at the inter-transverse sacro-lumbar joint limited. *Right* side, simply a massive process. Height at middle, 9 lines; distance from sacrum $\frac{1}{4}$ inch. Lower articular processes $\frac{1}{4}$ inch wider apart than upper. Distance between upper $2\frac{1}{8}$ inch. Difference more marked on 4th.

2. Male aged 40 (case No. 11 of Sacral variation; 1st coccygeal united to sacrum). *Right* transverse process massive, height at middle, 10 lines; bifurcated; descending division as large as a thick finger, passes downwards and outwards, and articulates movably with a cavity on outer and back part of wing of sacrum, which ascends to meet it only on outer side, where they articulate with the ilium. Line of articulation between sacrum and transverse process, oblique, outwards and upwards from the foramen. Auricular surface reaches up to the very

top of sacral wing, and a little upon the lumbar transverse process; and down, on both sides, to near the lower edge of the 2nd normal foramen. Lower articular process on this side faces almost straight forwards; and lower processes $\frac{1}{8}$ inch less apart than the upper. Width between upper, 2 inches. *Left* side, transverse process shorter than usual, and as thick as little finger; corresponds to upper division of the bifurcated right process; distance from sacrum, 4 lines.

3. Female skeleton. Vertebrae C. 7, D. 12, L. 5, S. 5, C. lost. Same subject as case 7 (b) of ankylosed short cervical ribs. *Right* transverse process of 5th lumbar vertebra, massive. Height at foramen $\frac{3}{4}$ inch. Short thick wing, rather than a bifurcation; upper angle corresponds to transverse process of left side, but is thicker. Below, articulates broadly, for $1\frac{1}{4}$ inch, with outer and back part of sacral wing, which has risen up to meet it; articulation directed obliquely outwards and upwards, and movable. In growing towards each other, most in front has been done by the sacrum, most behind by the lumbar wing. Only a very small part of the latter appears to have articulated with the ilium. *Left* transverse process, thicker than usual externally; distance from sacrum, about $\frac{1}{4}$ inch. Lower articular processes $\frac{1}{4}$ inch nearer each other than the upper are. Distance between upper, 2 inches. Neither upper nor lower quite symmetrical. Those of 4th equidistant. Lower processes of 3rd are $\frac{1}{6}$ inch wider apart than upper, but not so wide as those of 4th.

4. Male aged 47 (case 4, Thoracic variation. Very unequal 12th ribs). *Right* transverse process massive, 1 inch in height at middle; expanded externally as a wing, nearly $1\frac{3}{4}$ in breadth, anterior surface looking obliquely forwards and upwards. Outer and lower part of wing ankylosed to outer and back part of wing of sacrum, which has ascended to meet it; line of ankylosis 1 inch in length, directed obliquely upwards and outwards from the foramen. Free outer edge of wing slopes upwards and inwards to a blunt upper angle; and, below, supports the upper end of the auricular surface. Upper portion of auricular surface, $1\frac{1}{2}$ inch in length, is prolonged on ascending process of sacrum, and for about $\frac{1}{3}$ inch on wing of lumbar vertebra; lower portion, somewhat shorter, reaches down to opposite lower edge

of 2nd normal foramen. The wing-like expansion of the lumbar transverse process here presented, is remarkably like that of the corresponding part of the first sacral vertebra in cases 1 to 4 of sacral variation, in which the 5th lumbar vertebra appears to have been sacralised. *Left* side, transverse process, shorter and somewhat thicker than usual, distance from sacrum $\frac{1}{4}$ inch. Lower articular processes $\frac{1}{8}$ inch wider apart than upper, and not symmetrical. Width between upper, $1\frac{3}{4}$ inch.

Reference may here be made to the condition of the lumbar transverse processes in cases Nos. 5, 6 and 7 of lumbar variation, shewing six lumbar vertebrae. Although we sometimes speak of that condition as one in which a sacral vertebra has been given off to the lumbar region, the condition is simply that the 25th vertebra has remained free. The cases therefore serve to illustrate the approach of a vertebra to the sacrum, and there is greater symmetry. In each of the three, the transverse processes are larger than usual, and articulate by facets with back part of wing of sacrum, in case 7 on both sides, in cases 5 and 6 on the side on which the process is larger than on the other; and in these two cases, the greater transverse process has an articular facet for the ilium also. Case No. 4 of lumbar variation illustrates still better the advancing sacro-lumbar synostosis[1].

[1] *Occurrence of this change in the Gorilla.* In the Gorilla, and apparently also in the Chimpanzee and the Orang, the lowest lumbar vertebra more or less frequently becomes united to the sacrum in old subjects. This change appears to be by some considered as normal, by others only as not unfrequent. In the specimen of the gorilla in my possession, that of an adult but not old male, this vertebra (the 24th) is quite free, and shews no indication of that change of form by which it would come to resemble an upper sacral vertebra. No doubt, the upward elongation of the iliac wings, and the closeness and ligamentous connection of the last rib to the iliac crest, with the related lesser mobility of the lumbo-sacral articulations, place the gorilla favourably for the occurrence of this synostosis with advancing age; but, comparing my specimen with that figured by Professor Owen (*Trans. Zool. Soc.* Vol. v. plate 12, fig. 2), in which the 24th vertebra has become the broadest piece of the sacrum, I have great difficulty in believing that this vertebra would in the farther life of this individual have undergone such a change. Between its short blunt transverse processes and the upper border of the first sacral vertebra, there is a triangular gap, internally 4 lines, externally 9 lines in height. The greatest breadth of the sacrum, at the brim-line, is $3\frac{1}{2}$ inches, contracting upwards to under $2\frac{3}{4}$ inches. The breadth of the lowest lumbar vertebra, from tip to tip of its transverse processes, is the same as that of the sacrum at its upper border, a line less than the $2\frac{3}{4}$ inches. The blunt outer ends of these transverse processes, $1\frac{1}{4}$ inch in height, by $\frac{3}{4}$ inch in breadth, are but from 2 to 3 lines distant from the corresponding shallow and smooth recess in the ilium. I have noted considerable variation in regard to the free or sacralised

(2) *Variation of the lower Articular Processes of the 5th Lumbar Vertebra.* The articular processes of the 5th lumbar vertebra present the double character of great actual width apart, as compared with those of the vertebrae above them, and of greater width apart of the lower compared with the upper processes; an adaptation to the greater breadth of the human sacrum. The first piece of the sacrum presents the contrast of having its lower articular processes much nearer each other than the upper processes are. But these characters of the articular processes of the 5th lumbar vertebra are not invariable, nor are they distinctive of a 5th as compared with a 4th lumbar vertebra. The increase in width apart of the lumbar articular processes begins generally on the 3rd, and becomes marked on the 4th. While the lower processes of the 1st and 2nd are nearer each other than the upper processes of the same vertebra, those of the 3rd may be as wide apart as its upper processes, or a little wider. The lower of the 4th are wider apart than the upper by about $\frac{1}{4}$ inch, or it may be less; and the lower of the 5th are wider apart than the upper by from $\frac{1}{4}$ to $\frac{1}{2}$ inch. This is between the outer articular margins, but between the inner articular margins also shews the difference; which is not due to the processes having been turned round so that they face more forwards and backwards, but to actual carrying outward of the whole process, although the change of position and the change of direction are associated.

But while these differences are seen in a series, they will not serve to distinguish a 5th from a fourth, which presents the same characters absolutely, sometimes highly, while the 5th may shew them to a less than usual degree. Better characters are the thickness of pedicle, and the generally greater depth of

condition of this vertebra (the 24th) in the specimens of the gorilla in museums, and the differences may be referable to individual variation as well as to age; but the number of specimens altogether as yet in museums is not sufficient to afford ground for safe generalization on such a point. The cases of human variation above recorded, in which a 13th rib is developed, correspond in this respect to the normal condition in the gorilla and chimpanzee, except that the rib in them is more fully developed; while the cases of 5th lumbar vertebra uniting to the sacrum, correspond to what is at least a frequent if not the normal change in the anthropoids with advancing age. In man, however, the reverse change, that of leaving the 25th vertebra free, appears to be more common, tending to increase his lumbar region at the lower part; while the tendency in the gorilla is in the direction of decrease, by iliac as well as by costal encroachment.

the body before than behind. Farther, in some instances the lower processes of the 5th may not be so wide apart as the upper, though I have not met with a fourth in which it is so. 1. In one case (case No. 3 of imperfectly developed 12th ribs, and also case No. 5 of cervical rib; female), the lower articular processes of the 5th lumbar vertebra are exactly the same distance apart as the upper processes, while the lower processes of the 4th are $\frac{1}{8}$ inch farther apart than the upper. The lumbo-sacral processes are very little turned round, so that the sacral processes face very much inwards. 2. In another case, a detached 5th lumbar vertebra, the lower and upper processes are equidistant; the lower processes have the same inward direction as in the last case, but to a less degree. 3. Reference is made to other cases in the following summary.

Summary of the disposition of the articular processes in the cases in which the lowest lumbar vertebra is variously abnormal. It will be seen to be very various, appearing as if determined sometimes by functional circumstances, sometimes by the inherited character of individual vertebrae. In the four cases (variation of 5th lumbar vertebra) in which the 5th lumbar transverse process was articulated or ankylosed to the sacrum on one side, the lower articular processes of the 5th are wider apart than the upper in two (cases 1 and 4), and not so wide apart as the upper in two (cases 2 and 3). In the three cases of movable sixth lumbar vertebra (lumbar variation, cases 5, 6, and 7); in case No. 5, lower processes of sixth not so wide apart as upper; those of fifth $\frac{1}{4}$ inch wider apart than lower, and wide. In case No. 6, lower and upper processes of sixth equidistant: lower of fifth a little wider apart than upper, but not wide. In case No. 7, processes not wide apart; lower of sixth $\frac{1}{4}$ inch more apart than upper; lower of fifth $\frac{1}{8}$ inch more apart than upper. In case No. 3 (lumbar variation), also with movable 25th vertebra, lower processes both of sixth and of fifth are $\frac{1}{4}$ inch wider apart than their upper processes, but are not wide apart and look much inwards. In case No. 9 (lumbar variation), in which the sixth lumbar is the 24th vertebra actually, and freely movable, the lower articular processes are $\frac{1}{8}$ inch less apart than the upper; while the lower of the vertebra next above are $\frac{1}{8}$ inch more apart than the upper. In the cases in

which a lumbar vertebra appears to have been ankylosed to the sacrum (cases 1 to 4, sacral variation), the lower articular processes on the first sacral piece have the usual inward sacral position, compared with the upper processes. In case No. 1 of these, in which alone the movable vertebrae were present, the lowest lumbar (23rd vertebra) has the lower articular processes $\frac{1}{2}$ inch wider apart than the upper, and wide. In case No. 4 (lumbar variation) in which the sixth lumbar (25th) vertebra is partly ankylosed to the sacrum, the lower processes of that vertebra are $\frac{1}{2}$ inch nearer each other than the upper, which are wide ($2\frac{1}{4}$ inches apart); while the lower of the fifth are $\frac{1}{4}$ inch wider apart than the upper.

(3). *Variations of the upper Articular Processes of the Sacrum.* These processes vary frequently in direction, curvature, and size. It may be remarked that they usually face more backwards than the upper lumbar processes do. This sometimes goes so far that the sacral processes face almost directly backwards. Sometimes they are much more concave than the lumbar processes; in other cases almost flat, as when they face much backwards; but the curve is generally greatest at the inner and fore part. When flat, and facing but little inwards, they are mostly small; the much curved ones mostly large. Want of symmetry is not uncommon, both as to curvature and general direction. The variations of these processes indicate corresponding variations of the lower articular processes of the 5th lumbar vertebra, in addition to the varieties in width apart above noticed, but they are more easily studied on the sacrum.

(D) Variations of the Sacrum.

(a) Diminution in the number of Vertebrae composing the Sacrum. This condition is rare compared with the opposite one of increase. In case No. 6 (lumbar variation) we had an instance of a sacrum with only 4 vertebrae, in which there were 6 lumbar vertebrae, and 4 coccygeal. In that case the diminution was accounted for by the upper vertebra remaining free; in the following case the diminution appears to have been due to the lower vertebra remaining free.

Second case of adult sacrum composed of only 4 vertebrae. A fully ossified but small pelvis, the upper pelvis especially unexpanded, having on the whole the characters of the male more than of the female pelvis; upper parts of thigh-bones, which are present, muscular and shew very oblique neck. Sacrum normal above, as also the lowest lumbar vertebra, which is present. Only the first vertebra below the 4th sacral is present, the rest being lost. This piece is quite movable; body very short, 3 to 4 lines, and broad. Breadth where it articulates with sacrum, 10 lines, and concave transversely; lower end 6 lines transversely. Wings slender, especially left; these and left horn in contact with sacrum but not ankylosed. No distal horn. The form of this piece might pass it for either a 5th sacral or a 1st coccygeal. There may not unlikely have been 4 coccygeal pieces beyond, but, while the sacrum normally consolidates from below upwards, we have here what would have been the 5th piece remaining quite free, leaving a sacrum with 4 pieces. Canal opens at lower part of 2nd piece. Auricular surface goes down to opposite lower edge of second foramen. Breadth of sacrum almost 4 inches; length, in front, $3\frac{2}{8}$ straight (with movable piece $\frac{1}{8}$ inch more), along curve $3\frac{5}{8}$ (with movable piece $\frac{2}{8}$ more); depth of curve 6 lines (with movable piece 8 lines).

(b) EXAMINATION OF CASES OF VARIATION IN FORM OF THE UPPER SACRAL VERTEBRA, IN WHICH IT APPEARS TO BE THE LOWER LUMBAR VERTEBRA ADDED TO THE SACRUM. THE APE-LIKE SACRUM. Case 1. For a case in which the upper sacral vertebra must be considered as obtained from the lumbar region, from its peculiar form together with the absence of a dorso-lumbar vertebra, reference is made to case No. 8 under lumbar variation. The account of the form of the 1st sacral piece is specially referred to.

Case 2. *Wings of 1st sacral vertebra very deficient in front; sacrum of 5 pieces.* In a well-marked male pelvis. Brim-line of true pelvis is on 2nd piece. Brim-line of ilium bifurcates, the lower runs on 2nd piece of sacrum, the upper runs to 1st piece. Body of 1st inclined a little back from curve of sacrum. Upper surface of wings slopes very much forwards, beginning at lower edge of 1st foramen, especially on left side. Greatest

breadth of 1st piece, at upper end of auricular surface, $4\frac{5}{8}$ inches; of 2nd piece, at brim-line, $\frac{1}{4}$ inch less. But to the eye the first piece seems as if narrower than the 2nd, owing partly to the want of the usual much greater breadth of the 1st piece, partly to the first piece rapidly narrowing above the auricular surface. Neck of wing, as seen in front, considerably thinner than that of 2nd, which is unusually robust (9 to 10 lines) and like that of a first sacral piece. Even as seen obliquely, from above, the breadth of neck of wing of 1st piece is not equal to either the vertical or the antero-posterior measurement of neck of 2nd piece. Is ossified to 2nd by the wings only, a fissure still remaining at outer side of left foramen. Second not quite ossified to 3rd at body, or on right side. Traces of epiphyses of iliac crests still visible. Auricular surface reaches from middle of 1st piece down to opposite the upper $\frac{2}{3}$ of the 3rd foramen. Canal opens at 4th piece. Fifth piece resembles an ordinary 4th; breadth between tips of wings $2\frac{1}{2}$ inches; horns robust; lower end, breadth 1 inch, cartilaginous surface transversely convex and not much bevelled. Remainder lost. In this case the sacrum has only 5 pieces, while in case 1, and in the two following cases, it has 6.

Case 3. *Wings of 1st sacral vertebra very deficient in front; sacrum of 6 pieces.* Upper sacral vertebra closely resembling that of last case, but sacrum smaller and not quite fully ossified. Is ankylosed only by inner half of wings, as seen in front, the entire wing not yet ankylosed behind. Body inclined a little back from curve of sacrum. Wings slope much forwards, the slope beginning at outer edge of foramen. Greatest breadth, at upper end of auricular surface, $3\frac{6}{8}$; of second piece, at angle of auricular surface, $\frac{1}{8}$ inch less. Neck of wing, as seen in front view, is much thinner than that of 2nd, which is robust (7 lines) and convex, liker that of a first, for a sacrum of this size. Seen obliquely, as from above, the breadth is scarcely more than either the vertical or the antero-posterior measurement of the 2nd. Rounded off brim-line runs in on 2nd piece. Auricular surface; angle at middle of 2nd piece; upper portion goes up at very obtuse angle to lower and anterior third of 1st piece; goes

down as far as rather below middle of 3rd foramen, but apparently not reaching across the remains of the fissure between the 3rd and 4th pieces. Sixth piece ossified to 5th by horns and wings but not by body, no distal horns. Lower end 5 to 6 lines transversely. But for the peculiarities of the upper piece, this sixth piece might pass either as a fifth sacral, or as an ankylosed 1st coccygeal. Coccyx lost.

Case 4. *Sacrum very like the last, but large.* Upper vertebra ankylosed by whole of wings and side parts of body. Body and wings same characters as in last two cases. Breadth of 1st piece $4\frac{7}{8}$, of second $\frac{1}{8}$ less. Auricular surface, upper portion goes off at very obtuse angle, extending on 1st piece for an inch; angle is on wing of 2nd piece; lower portion goes down to rather below middle of 3rd foramen. Brim-line is on 2nd piece, but very much rounded off. First foramen, as in last case longest vertically, and is smaller in this case than the 2nd or 3rd foramen. Fourth foramen as small as 5th, and much smaller than 3rd. Sixth sacral piece united by wings, not by horns or most of body. Canal opens at 4th piece. No distal horns. Lower end 6 to 7 lines transversely.

In the absence of the vertebrae above and below, there can be no absolute certainty; but in these three last cases, as well as in the first case, the lowest lumbar vertebra appears to have been sacralised; the characters, indeed, being in all the three, more marked than in case No. 1 in which the deficiency of a dorso-lumbar vertebra is proved. The sacralisation in case 1 is carried so far that the upper piece attains the usual predominating breadth over the 2nd, and supports not merely the upper portion of the auricular surface, but also the angle of that surface, together with the brim-line, which the position of the angle determines. In case 1, there is also little or no deficiency in the expansion of the back part of the wing, behind the auricular surface. As a result of this deficiency in cases 2, 3, and 4, the posterior angle of the wing is placed far in, rising as a conical process, towards which the side of the wing, behind the auricular surface, slopes rapidly inwards. In case 1, however, as in the others, the upper end of the auricular surface is, as in the normal sacrum, the broadest part.

Reference may be made here to the account of the condition of the lowest lumbar vertebra in case No. 4 of lumbar variation. Comparing the specimens, it is seen that a little more advanced ossification would have converted that vertebra into an upper sacral piece, similar to that in this group of cases. It is seen also, that the low conical process on the upper sacral piece corresponds to the upper limb of the bifurcated lumbar transverse process, and is the end of the true transverse process. In an otherwise normal 1st sacral piece, this process is the end of the unexpanded transverse process part of the wing.

(c) EXAMINATION OF CASES OF SACRUM WITH 6 VERTEBRAE, IN WHICH THE UPPER IS OF UNUSUAL FORM, BUT IN ALL OF WHICH THE ADDITIONAL PIECE APPEARS TO HAVE BEEN GAINED AT THE COCCYGEAL END. Cases 5 and 6. In these two sacra, the wings of the upper piece have a marked downward and outward direction and are deficient in thickness. Case 5. A robust sacrum. First piece entirely ossified to 2nd, and body continues the curve of the sacrum, but wing is modified. Is deficient in thickness, so that, seen in a strictly front view, neck is considerably thinner than that of 2nd piece, while 2nd is not much more robust than usual. Direction is obliquely downwards and outwards, giving a very oblique brim-line, a little above the 1st foramen, and placing the auricular surface so low that its upper part is rather below the level of the upper edge of the 1st foramen. Wing deficient also at upper and outer part, so that upper part of auricular surface is very short. The conical process (ascending inter-transverse process) which often rises from some part of the posterior margin of the wing, and is well seen also in the next case, is here close to the articular process, and rises as high as it. Antero-posterior measurement of wing external to this, at middle, 1 inch; expanding outwards to only $1\frac{1}{4}$. Breadth of 1st piece $4\frac{7}{8}$, of second $4\frac{1}{8}$. Auricular surface reaches down to opposite upper edge of 3rd foramen. Canal opens at 5th piece. Coccyx present; 3rd and 4th pieces ankylosed; 2nd separate, and of usual form; 1st has evidently furnished the 6th vertebra to the sacrum. Fifth foramen, and union of the right horns, incomplete.

Case 6. A well-marked female pelvis, very capacious, and somewhat twisted to left side in front. Body and wing of 1st sacral vertebra as in last case, but wing not so deficient in expansion at upper part of sacro-iliac articulation. In strictly front view, neck not thicker than that of 2nd piece, which is not unusually robust. Brim-line passes obliquely upwards to promontory, a little above 1st foramen, above the plane of the rest of the pelvic brim. Breadth of 1st piece $4\frac{5}{8}$, of 2nd piece $3\frac{4}{8}$. Auricular surface reaches down to opposite upper edge of 3rd foramen. First foramen, as in last case, unusually large, especially in vertical direction. Canal opens at 4th piece. Sixth piece appears to be the 1st coccygeal, ankylosed by body and left horns; has short wings, above which are widely open notches; lower end 5 to 6 lines transversely. Rest of coccyx lost.

Although the want of thickness, and the lateral slope, of the wings, in these two cases, is sufficiently marked to attract notice, this condition is not to be confounded with that presented by the preceding four cases, in which the fore part of the wing (that where a true sacral vertebra is developed from a rib) is undeveloped, giving the ape-like form to the upper sacrum.

Cases 7 and 8. In these two cases, both well-marked specimens of female pelvis, the downward direction of the wing is seen in a less degree, but there is no deficiency in breadth of wing externally, and the neck, as seen in front, is somewhat thicker than the neck of the 2nd vertebra. Breadth of 1st piece in each, $4\frac{7}{8}$ inch; of 2nd piece, 1 inch less. In one (No. 7) the three nodular pieces of the coccyx are present, the first piece ankylosed to the sacrum and forming its 6th piece. Sacro-iliac articulation goes down to nearly opposite upper part of 3rd foramen. In the other (No. 8) the two distal pieces of coccyx are broken off, leaving one with the usual characters of the third piece, and the first piece ankylosed to the sacrum by body and right horns. Wings of latter transverse, leaving 5th foramen as a wide notch. Sacro-iliac articulation goes down to opposite nearly the middle of 3rd foramen.

Cases 9 and 10. Two well-marked male pelves. Wings of 1st sacral vertebra, though massive enough, attract notice as having more downward and outward slope, and also more for-

ward slope, than usual; giving a brim-line more oblique, and less distinct, than usual. In one (No. 9) a male aged 48; breadth of first piece $4\frac{6}{8}$ inch, of second $3\frac{5}{8}$. Sacro-iliac articulation reaches down to opposite rather below upper edge of 3rd foramen. Coccyx, 3rd and 4th pieces partially ankylosed; 2nd free; 1st completely ankylosed to sacrum, by body wings and horns. It has no distal horns but abrupt eminences, and 2nd piece has minute proximal horns and commencing transverse processes. In the other (No. 10) a male aged 30; breadth of first piece $4\frac{7}{8}$ inches, of second piece 4. Sacro-iliac articulation goes down to opposite upper $\frac{1}{3}$ or $\frac{1}{4}$ of third foramen. First coccygeal piece ankylosed to sacrum by wings, imperfectly by body, horns in contact. Second piece has minute horns and commencing wings, and is free. Third piece, a triangular nodule, also free. Fourth piece wanting and has, apparently, been lost.

(d) EXAMINATION OF OTHER CASES OF SACRUM COMPOSED OF 6 VERTEBRAE, BY ADDITION OF THE FIRST COCCYGEAL.

Case 11. Male aged 40. Coccyx, three distal pieces, all separate, and nodular. First piece, wings and horns short, is partly ossified to sacrum by body, forming the 6th piece of sacrum. Canal opens at lower part of 4th piece. Right transverse process of last lumbar vertebra large, bifurcated, and articulates with sacrum (see case 2 of variation of 5th lumbar vertebra).

Case 12. Male aged 34. First coccygeal ossified to sacrum, by right wing and right side of body; left 5th foramen widely open; horns do not meet. Rest of coccyx one ankylosed mass, with constrictions which might be held to indicate either 3 or 4 pieces, without any processes. Canal opens at lower edge of 4th sacral piece. Auricular surface reaches down to nearly upper edge of 3rd foramen.

Case 13. Well-marked male pelvis. Three distal pieces of coccyx ankylosed to each other. First piece ossified to sacrum by body and horns; wings transverse, leaving 5th foramina as wide open notches. Auricular surface goes down, on left side, to opposite middle of 3rd foramen; on right side, not quite so far.

Case 14. Female skeleton; adult but of short stature. First coccygeal vertebra, united to sacrum by body, wings, and horns. Nodular pieces of coccyx ankylosed into one bone, with 3 constrictions; doubtful whether this coccyx has 5 pieces, or a 4th with hour-glass contraction. Canal opens at lower part of 4th sacral piece. Auricular surface reaches down to near upper edge of 3rd foramen.

Case 15. Female pelvis. Traces of epiphyses still visible. First coccygeal vertebra ossified to sacrum by right horns; motion at left horns and at body. Wings short, and 5th foramina very wide notches. Rest of coccyx lost. Canal opens at 5th piece. Auricular surface reaches down to opposite upper $\frac{3}{4}$ of 2nd foramen, but a fissure of development, still remaining, distinctly shews that the ilium is $\frac{1}{8}$ inch from touching the 3rd sacral vertebra.

Case 16. Female pelvis. Aged 32. A sixth vertebra united by body, wings, and horns to sacrum. Rest of coccyx lost. Canal opens on 5th piece. Auricular surface goes down to lower edge of 2nd foramen.

Case 17. Fully ossified but small pelvis. Sex uncertain. Same as last case, but left horns not united, and wings not so broad. Canal opens on 5th piece. Auricular surface goes down to rather below upper edge of 3rd foramen.

(e) VARIATION IN THE NUMBER OF SACRAL VERTEBRAE WITH WHICH THE ILIUM ARTICULATES. *Development of the parts which support the auricular surface.* It is evident enough in young sacra, that the upper piece forms much the largest part of the foramen, but specimens in which consolidation is nearly completed shew the line more precisely. The part next the foramen has consolidated first, and the fissure passes outwards opposite a little above the lower edge of the foramen, undulating, but on the whole horizontally, whether seen before or behind; and opens externally, the edges curving upwards and downwards. Upon the upward and outward projection thus formed by the shoulder of the 3rd vertebra, the lowest part of the ilium rests; the cartilage, or bone, of the lateral

epiphysis intervening here, as well as higher up, in the unfinished bone. Taking the limits of the anterior foramen proper, from a third to a fourth, or less, of the foramen is formed by the 3rd vertebra; but the outer part of the fissure may be quite down to the level of the lower edge of the foramen. If, therefore, the auricular surface does not pass below the middle of the 2nd foramen, we may conclude that the ilium has not rested on the 3rd vertebra; and that, unless it has passed down to nearly opposite the lower edge of the foramen, there is uncertainty whether it has reached upon the third. Young specimens farther shew that the sacral ribs have expanded so much, antero-posteriorly, at their outer part, that they form much the greater part, about $\frac{3}{4}$, of the breadth of the lateral surface, supporting the whole auricular surface and part of the ligamentous surface behind it.

Varying extent of auricular surface. Cases in which it rests on only two vertebrae. A projection, seen in a front view, forming a mid-lateral angle, indicates generally the lower end of the auricular surface, but careful inspection is required, in front and behind, before concluding as to the true level in relation to the foramen. It will then be found that the extent to which the articulation passes down upon the 3rd vertebra varies considerably, and that sometimes it rests only on the 1st and 2nd vertebrae. The latter condition appears to occur more frequently in the female than in the male. In 20 specimens of sacrum composed (with one exception, a male) of 5 pieces, in which the sex is certain, 12 female, 9 male, the position of the lower end of the auricular surface is as follows. In the twelve *female* specimens, it does not reach to the third vertebra in four, and probably in a fifth; it reaches on the third vertebra certainly in two, probably in other two, while in one it probably does so on one side and probably not on the other; in the remaining two it is uncertain. In one of those in which it rests on two vertebrae only, (a characteristic and wide female pelvis, sacrum much curved,) it reaches only to the upper edge of the 2nd foramen; and in another (sacrum very little curved) to the middle of the 2nd foramen. In none of the twelve does it go down farther than just a little below the lower edge of the 2nd foramen. In the 9 *male* specimens, it goes down upon

the 3rd vertebra in 7; in one (with remarkably wide upper pelvis) it is doubtful, probably touching the 3rd on one side only; and in the ninth (a robust middle-sized skeleton, case No. 1 of ten sacro-coccygeal vertebrae) it is not lower than the upper two-thirds of the 2nd foramen, and does not appear to have touched the 3rd vertebra. In most of the seven, it goes well upon the 3rd, the farthest being to a little below the upper edge of the 3rd foramen. In one, an adolescent specimen, in which it goes to midway between the 2nd and 3rd foramina, it is seen to rest for $\frac{1}{4}$ inch upon the third vertebra.

Position of the auricular surface in the cases of abnormal sacrum. In the cases of more or less abnormal sacrum above noted, the position of the auricular surface is mentioned with each. In the third group ((d) cases 11 to 17, each of six pieces, the sixth obtained from the coccyx) it extended upon the third vertebra freely in two of the males (12 and 13), and probably in the third (11), and freely in the specimen (17) of uncertain sex. In the three female specimens, certainly in one (14), probably in one (16); and in the third (15) though reaching opposite $\frac{2}{3}$ of the 2nd foramen, the fissure shews that it does not reach the 3rd vertebra. In the second group ((c) cases 5 to 10, sacra of 6 pieces, upper piece more or less abnormal, but 6th piece obtained from coccyx) it reaches on the third vertebra freely in all, including three female specimens; in one, reaching nearly to the upper edge of the 3rd foramen, in the other five, reaching farther down. In the first group ((b) cases 1 to 4, in which upper vertebra appears to be 5th lumbar added to sacrum), the auricular surface rests on three vertebrae, being the borrowed vertebra and the two upper true sacral vertebrae. In one (case 2) it reaches down to very near the 4th piece.

In the five cases of a dorso-lumbar vertebra more than usual (lumbar variation, cases 3, 4, 5, 6, 7) the ilium articulated with the vertebrae as follows. In case No. 5, with the sixth lumbar vertebra on both sides, by a small facet, largest on the right side; with the sacrum, on right side apparently with two, on the left side apparently with three of its five vertebrae. In case No. 6, with the sixth lumbar vertebra on right side; with the sacrum, on right side with two, on left side

apparently with three of its four vertebrae. In case No. 7, ilium does not touch the sixth lumbar vertebra; articulates with upper two of the five sacral vertebrae, and apparently only by ligament with the third. In case No. 4, in which lowest lumbar is partly sacralised, ilium rests on small part of sixth lumbar on right side, an ascending process of sacrum intervening on left; and on two of the five sacral vertebrae on each side. In case No. 3, ilium not in contact with transverse processes of sixth lumbar it rests on three of the five sacral vertebrae.

(f) VARIATION IN THE FORM OF THE AURICULAR SURFACE. On examining a series of innominate bones and sacra, the bend of the sacro-iliac articular surface is seen to vary much; sometimes it is very obtuse, sometimes rectangular or less. This is determined by two distinct conditions, the conjunction of which may give either form in an exaggerated degree. Less complete development of the fore part of the wing of the first sacral vertebra, giving obliquity to the portion above the angle; and little curvature of the sacrum, influencing the direction of the part below the bend, together contribute to the obtuse-angled variety, strongly marked in the ape-like sacrum. The opposite conditions determine the rectangular variety. Want of symmetry, as to breadth, and as to longitudinal extent, up or down, is occasionally seen.

(g) CASE IN WHICH THE SACRAL CANAL IS OPEN IN ITS WHOLE LENGTH. Sacrum of 5 pieces; otherwise well formed, and well ossified, but line of union between bodies of 1st and 2nd pieces is open at middle in front, and same between 3rd and 4th, and 4th and 5th, pieces on posterior aspect. Laminae about $\frac{1}{2}$ inch from meeting; form a continuous smooth plate on each side internal to posterior foramina which ends in a smooth nearly straight margin. Slight projections at the edge at the 1st and 2nd vertebrae; narrowest part is at 2nd, gap widening a little upwards and downwards. Edges run up into inner side of articular processes, down into horns of moderate length.

(E) VARIATION OF THE COCCYX.

(a) DIMINUTION IN THE NUMBER OF THE COCCYGEAL VERTEBRAE. Instances of the movable coccyx composed of only

3 pieces are of no value as bearing on the question of absolute numerical variation, unless there is present at least a well-formed sacrum of five pieces, including a well-formed upper sacral piece. Even then the seemingly suppressed vertebra may be found as a sixth lumbar, as we saw in case No. 5, of lumbar variation. Case No. 9 of the same group, shews 3 coccygeal with 5 sacral, yet the nerves seemed to indicate that the suppressed vertebra was from higher up. But, considered as a regional fact, cases of the movable coccyx composed of only 3 pieces are common; and considered as a serial variation, cases of 3 coccygeal pieces along with 5 sacral occur occasionally (as in cases Nos. 5 and 9 of lumbar variation) while cases of 3 coccygeal with 6 sacral, the upper sacral not borrowed, are common, as in the seven instances in the third group of cases (Nos. 11 to 17 of sacral variation), and apparently also in the six cases in the second group (cases Nos. 5 to 10).

(b) INCREASE IN THE NUMBER OF THE COCCYGEAL VERTEBRAE. *Remarks on sources of fallacy.* Cases may occur in which the 5th sacral vertebra instead of consolidating first, has remained separate, of which the case of a sacrum with only 4 pieces, given under sacral variation ((*a*) second case), is an example; and probably also case No. 2 (*b*), although the sacrum had 5 pieces. In such cases the apparent coccyx may have had 5 pieces, but in these two cases the coccyx had been lost. But it is in my experience rare to find the coccyx presenting five pieces, besides the five sacral pieces. The first piece is easily enough recognised, either separate or ankylosed to the sacrum, but sometimes the nodular pieces are so united that no reliable conclusion can be drawn as to how many pieces there had been. Putting aside such specimens, there remain others in which it is not easy to decide how far a kind of constriction which is sometimes seen on the 4th, is to be accepted as evidence of a 5th having existed. But after the study of a series of well-formed specimens of coccyx in various stages of ankylosis, it becomes in most cases easy to recognise where a union has taken place, the examination being made on both aspects and by the help of a magnifying power. Besides the lateral notches, a groove runs across before and behind, and is sometimes quite distinct on one aspect when it is

obscure on the other, generally most distinct on the dorsal aspect. Of the three distal pieces, the 3rd and 4th are found united when the 2nd is still free; and in cases in which the three distal are united, the constriction between the 3rd and 4th is the least marked.

Forms presented by the respective coccygeal vertebrae. The *first* piece, either separate or united to the sacrum, has almost always more or less developed horns and wings. The *second* is generally bluntly triangular, and generally broader than long. In cases Nos. 9 and 10 of sacral variation, males aged 48 and 30, in which the first coccygeal piece is sacralised, the second, (the first free piece,) presents short wings and slight ascending horns, and is intermediate in size and form between the usual first and second coccygeal. The *third* is usually square-shaped, with rounded angles, and may also be broader than long. The *fourth* is of various forms; may be broader than long, may diminish to a blunt point, or to a very slight bifurcation, or may have a semilunar termination somewhat like the end of a digital phalanx; or it may be longer than usual, and present the appearance of a constriction. In some instances the form of this hour-glass 4th piece appears to result only from a semilunar expansion at the end, the constriction wanting that regularity and smoothness which generally characterise the groove between two united pieces; while in other specimens the indication of separation between a third and fourth has not greater distinctness. Section does not appear to help. In two specimens before me of section of normal sacrum and coccyx, in which the three nodular pieces of the coccyx are ankylosed but plainly indicated externally, the cancellous tissue of the three nodular pieces has become continuous, at least at the centre. It is not that there is reason to doubt the probability or the fact of the occurrence of a true additional coccygeal vertebra, but I desire to caution the observer against being too easily satisfied with appearances on this score. Putting aside all such doubtful cases, the following are two instances of the occurrence of ten pelvic vertebrae.

1. *Case in which there are ten Sacro-Coccygeal Vertebrae, in addition to the full number in other regions of the spine.*

Male skeleton, fully ossified, middle-sized, and of good muscularity. Fifth sacral piece normal except that body is shorter, reaching only $\frac{1}{3}$ to $\frac{1}{2}$ inch, instead of $\frac{3}{4}$ inch, below level of lower edge of 4th foramina. *Sixth* piece partially ankylosed here; separate behind and at right side, ankylosed in front and at left side, but line visible. Breadth at junction with 5th piece $1\frac{1}{2}$ inch, at distal end $\frac{3}{4}$ inch, edges curving upwards and outwards from lower to upper end. No wings or horns from either this or next piece, but 5th sacral piece sends downwards strong horns, passing a little beyond the line of union between the bodies of the 5th and 6th pieces. Owing to shortness of 5th sacral body, and absence of wings from 6th, the lower lateral angles of sacrum project abruptly, and there is no attempt to enclose a 5th foramen. At a more advanced age there would probably have been little or no trace of a sixth piece having existed here. *Seventh* piece, movable on 6th; triangular; length 4 lines; breadth, 9 lines above, 6 lines below. Small tubercle on left side where a horn would grow. Eighth, ninth, and tenth pieces ankylosed to each other, and partially also to the seventh, with very distinct notches and grooves of separation, ankylosis of the two distal most advanced. Length of each of the three last, 3 lines. Breadths as follows; of eighth piece, 7 lines at upper part, diminishing to 5; of ninth piece, 5 lines, a little more above, a little less at lower end; tenth piece, 4 lines at middle, diminishing a little to a rounded termination. Total length of the five pieces, 19 lines; of the last four pieces 13 lines.

2. *Another case in which there are ten Sacro-Coccygeal Vertebrae.* Female aged 53. Six pieces ankylosed in sacrum, 7th piece free, 8th, 9th, and 10th ankylosed together. Sixth piece ankylosed to fifth by body and by robust horns, wings very short, forming lower end of notch instead of 5th foramen. Seventh piece, no horns or wings; length, 4 lines in front, 6 lines behind; breadth, 9 lines above, 6 lines at lower end. Length of the three distal pieces together, 9 lines behind, 7 lines in front; lengths of each separately, on dorsal aspect, eighth piece 4 lines, ninth and tenth pieces each $2\frac{1}{2}$ lines. Breadths at middle, of eighth piece, 5 lines; of ninth, 4 lines; of tenth,

3 lines, diminishing a little to a rounded end. Total length of the four distal pieces, 15 lines; including the sixth piece, 20 lines in front, 24 lines behind. Constrictions between the three distal pieces not nearly so well marked as in last case, but are sufficient. The ankylosis of the first piece to the sacrum is also more complete in this case.

(c) ORDER OF UNION OF THE COCCYGEAL VERTEBRAE. EXTERNAL INFLUENCES. The usual order of union of the coccygeal pieces, according to my observation, is first between the 4th and 3rd, next between the 3rd and 2nd, while the 1st remains separate or unites with the sacrum. The three distal pieces, more or less ankylosed, form one body moving freely on the first, and it is this probably which most commonly passes for the coccyx in practice. They are commonly said to be later in uniting in the female than in the male. In a specimen from a female aged 43, the 5 sacral and 4 coccygeal vertebrae are already all united into one bone, but there are traces of bony excrescence at various parts of the sacrum. Besides the influence of sex and of natural variability, the sedentary and other habits of the individual, must, especially in civilised life, influence the length of time during which the coccyx retains its mobility. In persons who sit while working, and in those who are much in the saddle or in the carriage, the coccyx must be kept in frequent passive motion; while in the recumbent posture it is freed both from external influences and from muscular traction.