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17

Pressure-changes in the Skeleton

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A REMARKABLE EXAMPLE OF THE MANNER IN WHICH PRESSURE-CHANGES IN THE SKELETON MAY REVEAL THE LABOUR-HISTORY OF THE INDIVIDUAL.

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In the *Transactions of the Pathological Society*, 1886, I published a paper on the "Causation and Pathology of the so-called Disease Rheumatoid Arthritis and of Senile Changes." In it I showed that the changes which are described as being characteristic of the presence of this so-called disease are the results of purely physiological processes.

They form a very complex group, and depend for their existence upon pressure in some form or another, the term pressure being used in a very wide signification.

I was able to subdivide them into the four following classes:—

1. Changes which result from the exercise of enormous pressure *at one time*, as for instance those which ensue in the head of the humerus or of the femur after falls upon the shoulder or hip.

2. Changes which result from the *frequent* exercise of very considerable pressure over a long period of time, as in labourers who carry heavy loads upon their heads, backs, or shoulders, or in those who are affected with some deformity which alters the normal mode of transmitting the weight of the body to the lower extremities, as in shortening of one leg from fracture or disease. In such a case, changes are most marked in the hip and sacro-iliac joints on the affected side, the spinal column also showing alterations dependent on the deformity.

3. Changes which ensue in old age from the acquired condition of habitual flexion of the trunk and limbs, and the limitation in the extent of articular movements consequent on the absence of the movements of extension, abduction, and extreme flexion.

Many of these changes are due, not so much to pressure, as to the absence of accustomed pressure. This is seen in the filling up of the floors of the olecranon and coronoid depressions by the deposit of layers of bone upon it so as to form an osseous elevation, or by the formation of a pedunculated mass of bone in a fringe of synovial membrane.

Many other changes consequent on the partial or complete dislocation of several joints also occur in old age.

4. Severe attacks of subacute or chronic rheumatism place the affected part in a condition which is identical with that present in old age, and changes ensue which are similar in character to those then present, though they vary with the vitality of the osseous system of the individual.

I showed that the manner in which bone and cartilage react to pressure depends to a very great extent upon the vitality of those tissues; that the pressure which in elderly subjects or in those of low vitality destroys the articular cartilage and the subjacent bone, rendering the latter eburnated, and determining the formation of additamentary bones, produces in a young subject a similar alteration in the form of the articular surface, without affecting the vitality or continuity of its cartilaginous covering.

I also pointed out that, if you increase the extent of the movements permissible in an articulation, the synovial membrane and periosteum beyond the margin of the original articular surface form bone and articular cartilage, which are identical in function and character with that already present, and that if you limit the movements of a joint, or if partial or complete displacement of the opposing cartilaginous surface is produced, that portion of the articular cartilage which no longer receives the accustomed friction and pressure of that originally opposed to it becomes converted into synovial membrane and areolar tissue.

The above four subdivisions will include all changes which ensue as the result of pressure, and these I have designated by the term *pressure-changes*. The conditions which are usually regarded as characteristic of the disease *rheumatoid arthritis* are included as a sub-class of *pressure-changes*. In a paper in the *Guy's Hospital Reports*, 1886 ("Pressure Changes in the Trunk and Shoulder Girdle,"), I have given many instances of these pressure changes, and I have added many more in the paper in the *Pathological Transactions* already alluded to.

Since writing those papers I have steadily pursued the study of the subject, with the satisfaction of being able to verify hypotheses which I may have put forward then with some slight hesitation, and to satisfy myself still more absolutely as to the accuracy of the views which I have expressed on the subject of the causation of rheumatoid arthritis.

I will now give the following very interesting example of the manner in which the presence of pressure-changes in the skeleton may enable us to detect the habits and labour-history of the individual. In this description, and for the future, I will limit myself to the use of the term *pressure-changes*, avoiding altogether the use of the less comprehensive and vaguely definable term *rheumatoid arthritis*.

Since this is the first instance of this particular group of changes which I have yet observed, I must state at once that, as I have not had an opportunity of verifying the conclusions at which I have arrived, I will therefore put them forward hypothetically and subject to the result of future experience. At the same time, I may say that I have no doubt, in my own mind, that subsequent investigations will serve to verify them.

The body was that of a man who died at the age of sixty-nine of chronic bronchitis. He was largely and powerfully built, and his bones and muscles were in very good condition. It was evident, from the general appearance of his bones and joints, that he had been employed at some form of active and heavy manual labour for many years of his vigorous life.

The *sternum* was strong and thick. The manubrio-gladiolar articulation was firmly amphiarthrodial in character, and, though the opposing surfaces of bone were broad, they were not so dense as is usual in labourers who carry loads upon the trunk. There were no so-called additamentary bones in the back part of the joint.

The *clavicles* were very thick and strong, and their outer thirds were particularly deep. Their inner extremities, especially that of the right clavicle, extended downwards, backwards, and inwards to a greater extent than in any that I have yet observed. The clavicular facets on the manubrium presented a corresponding change in their form and direction. This condition, which was obviously an exaggeration of that normally present, appeared to have been developed with the object of preventing forward displacement of the inner extremity of the clavicle, when its outer extremity was forced backwards and perhaps upwards by a pressure of no small amount.

The margin of the facet on the under surface of the inner extremity of each clavicle was everted and lipped. The rhomboid ligament was very dense and broad, and there was no indication of the formation of a bursal cavity in relation with it, nor was there any displacement of the insertion of the subclavius muscle. These facts show that the weight, which had been habitually applied in a downward direction to the outer extremities of the clavicles, though considerable, was not so great as in labourers who sustain loads upon their trunks. This is also shown by the circumstance of the 1st costal cartilage being but partly sheathed by bone. The movements permitted by the sterno-clavicular articulation were very free within certain limits.

The *scapulæ* were strong, and the acromion process was thick. The corresponding facets on the acromion and clavicle were large, and though the fibro-cartilage which usually intervenes was completely absent, the margins of the facets were not lipped. They were connected by loose fibrous capsules. The coronoid and trapezoid ligaments were short and strong. A bursal cavity existed in front of these ligaments on the right side, but it was not so well developed as in labourers who carry loads upon their trunks,—who retain the

shoulder-joint in a position of complete flexion in order to support the load.

These facts show that the scapula was moved freely upon the clavicle, and that the movement of extreme flexion of the right shoulder-joint occurred very frequently. It is also extremely probable that the arm was loaded during the performance of these movements.

The *shoulder-joint* presented some changes. The long tendon of the biceps passed freely through the bicipital groove, and ended in the glenoid ligament. On the right side the glenoid ligament was separated completely from the upper third of the margin of the glenoid cavity, being connected to it indirectly by a thin membrane. The upper part of the glenoid cavity was slightly increased in area. The cartilage covering the lower part had been converted into synovial membrane and areolar tissue, which formed an elevation whose surface projected beyond the level of the articular cartilage. These changes were present on the left side in a slighter degree.

Now, the above conditions are found associated with the upward displacement of the head of the humerus which ensues in old age, but in this subject the abductor muscles, like the other muscles of the shoulder, were remarkably well developed, and there was no change in the form of the upper extremity of the humerus. I think we may conclude from this that the upward displacement of the head of the humerus was due either to the raising action of the flexor muscles and deltoid, or to force or resistance exerted upwards in the direction of the shaft of the humerus, or to both acting together.

The *elbow-joints* showed well-marked and peculiar pressure-changes. The articular cartilage covering the trochlear surface of the humerus and of the ulna was thick and normal in appearance, in no part presenting any degenerative change. The area of the opposing articular surfaces of ulna and humerus was extended by marginal bony growth, the surface of which was covered by articular cartilage, which was continuous and identical in character with the original articular layer.

Besides this increase in articular area, the olecranon and coronoid depressions were filled up to a great extent by bone, so that the left fore-arm could not be extended on the upper arm beyond an angle of 155°, nor could it be flexed beyond an angle of 75°. On the right side the movements of flexion and extension were still more limited. The margins of the coronoid and olecranon processes were rendered very thick, and these presented flat eburnated surfaces, which articulated in extreme flexion and extension with corresponding facets formed on the masses of bone which filled up the floor of their corresponding fossæ.

It is obvious that the increase in breadth and strength of the area of the humero-ulnar articulation took place in order that the elbow-joint might be rendered strong and firm, so that the fore-arm supporting a considerable load could be rapidly flexed on the upper arm with ease and safety to the elbow-joint through an angle of 80°. The filling up of the floors of the olecranon and coronoid depressions with bone,

and the increase in the thickness of the extremities of the olecranon, and especially of the coronoid process, and the remarkable eburnation of the opposing surfaces of coronoid process and of the bone filling up the coronoid depression, show that in the performance of his occupation it was never necessary to flex or extend the fore-arm completely,—that the limited movement through about 80° was the normal one, and that this limitation in movement round a transverse axis was advantageous in rendering the elbow-joint stronger and more reliable for its acquired function.

The radial head of the humerus differed in a very striking manner from that of the trochlea. The thick layer of articular cartilage which covered the latter surface terminated abruptly on the margin of the radial head, whose surface was completely deprived of cartilage, and was, instead, densely eburnated and polished. Much of the original articular lamella of bone had been removed, and this had evidently been the result of the friction and pressure exerted by the head of the radius upon it.

Filling up the little fossa above the radial head and limiting flexion of the fore-arm was a boss of bone which was facetted and eburnated by the margin of the radial head. The upper surface of the head of the radius was completely deprived of its articular cartilage. It was deeply cupped, eburnated, and polished. It was not uniformly concave, there being a slight elevation in front. On placing the parts in position, it was seen that the movements permitted by the radio-humeral articulation was one of flexion through a limited angle, associated with one of rotation of the shaft of the radius through about 100°, so that the hand was carried from the supine position to one of pretty complete pronation.

From the amount of polished eburnation of the opposing surfaces of the radius and ulna, it is obvious that very much force was exerted upon the radial head of the humerus by the head of the radius. This may have been due to resistance to the forward movement of the hand, or to a heavy load carried in the hand during the movements of flexion and rotation, or to both together. The last appears most probable from the examination of the character and arrangement of the eburnated surfaces.

The sigmoid cavity on the ulna was considerably increased in area by the deposit of bone on its posterior margin, and in such a way as to change the general direction of its concave surface, so that it no longer looked outwards, but outwards and forwards. Attached to the anterior limit of the facet was a concave mass of bone, which continued the direction of its concavity. This mass was connected to the sigmoid cavity by ligamentous tissue, and formed a so-called additamentary bone. Like all these so-called additamentary bones, it was not a symptom of a so-called disease, but it served a definite and useful physiological function. When the fore-arm was extended to nearly its extreme limit upon the upper arm, this so-called additamentary bone formed a portion of the socket for the head of the radius, and as the angle between the fore-arm and upper arm was diminished, this portion of bone was gradually displaced upwards,

but in doing so, it still formed a part of the socket, in which the head of the radius could rotate without its flexion being interfered with by its presence.

The margin of the radial head was smooth, and covered by cartilage over nearly three-fifths of its area, this smooth surface being limited in front and behind by marginal bosses, which also limited the rotation of which the radius was capable. The non-articular margin presented at its lower part irregular bossing of bone.

In the *lower radio-ulnar articulation* the area of the opposing facets was limited, the margins being abruptly defined and prominent. They were covered by a thin layer of articular cartilage. The inter-articular fibro-cartilage was perforated along its attachment to the margin of the radius, except where it was continuous with the anterior and posterior inferior radio-ulnar ligaments. The head of the ulna was seen through the perforation in the fibro-cartilage.

In some labourers I have seen this fibro-cartilage completely removed, and the opposing surfaces of cuneiform bone and ulna densely eburnated. This perforation is obviously due to force acting on the radius, displacing it a little upwards, and pressing upon and destroying the tense fibro-cartilage.

The *thorax* was well made and typically masculine in character. The 1st pair of ribs were strong, but not very broad. On pressing on the 1st costal arch in a downward direction no tilting was obtained, its articulations with the column being particularly firm and allowing of very little movement.

The 1st rib on the right side articulated with the spinal column in a manner which I had never before seen (see fig. 1). Two prominent bony processes projected outwards from the bodies of the 7th cervical and 1st dorsal vertebræ in such a manner as to enclose between them the head of the 1st rib, for which they formed a socket. This socket only permitted of a rotation of the rib around the transverse axis of its head. The process of bone which projected from the body of the 7th cervical was much the larger. It was more than half an inch long and very dense. It altogether opposed any upward movement of the head of the rib.

The connection of the rib to the transverse process of the 1st dorsal vertebra was very strong, and allowed of very limited movement. Though the connection of the left 1st rib with the column was very firm, there was no new bone formation as on the right side.

The appearances presented by the right costo-vertebral articulation were altogether different from those seen in labourers who carry loads upon their trunks. In them the head of the rib is large and flat, and allows of considerable movement in some cases, as it receives the powerful pressure transmitted to it through the clavicle.

In this case, then, it would appear that the character of the work performed necessitated a very considerable fixation of the 1st costal arch, and especially of its right half, so that the right clavicle might have a firm or even rigid base to work upon. Also, that the amount of force transmitted to it by the clavicle was not enormous, though probably considerable, and that the movements performed by the 1st

costal arch were almost solely respiratory, the anterior extremity of the rib moving upwards and downwards in a vertical plane around a transverse axis, which passed through the head and tuberosity of the rib.

The *cervical column* showed no pressure-change, its anterior surface being quite smooth and its fibro-cartilages intact. This circumstance alone would at once remove any possibility of the man's having carried heavy loads upon his trunk.

The *dorsal column* presented two slight lateral curves. The upper was formed by the upper five or six dorsal vertebræ and the 6th and 7th cervical. Its convexity was directed to the right. The lower was formed by the remaining dorsal vertebræ and the 1st and 2nd lumbar vertebræ. Its convexity was directed to the left. The right and anterior margins of the bodies of the 9th and 10th dorsal vertebræ were connected by a prominent boss of bone, which presented a slightly serrated suture. The adjoining margins of the 10th and 11th vertebræ were lipped by the formation of some marginal bony growth. The intervertebral fibro-cartilages between these several vertebræ were normal, and showed no signs of being compressed, and, except in the case of that which was bridged over by bone, they allowed of very free movements of flexion and extension of the column.

The *lumbar curve*, examined in its entirety, was of an average convexity; but on examining its anterior surface more carefully, while the subject was in the supine position with the trunk completely extended, it was seen that the curve formed by the upper four lumbar vertebræ terminated abruptly on a plane anterior to that of the 5th lumbar, the 4th vertebra appearing to be displaced a little forwards from the upper surface of the last lumbar vertebra and sacrum. The intervertebral substances between the several lumbar vertebræ and sacrum were very thick, and allowed of the column being freely flexed and extended.

The adjoining lateral and anterior margins of the bodies of the 4th and 5th lumbar vertebræ were much lipped by the deposit of new bone upon them. This was much more abundant towards the sides than in front, and on the left side than on the right, and on the upper margin of the 5th vertebra than on the lower margin of the 4th.

On moving the thorax an extraordinary amount of rotation was seen to take place between these two vertebræ, and careful examination showed that the movement that had been habitual during lifetime was one of rotation of the thorax and upper four lumbar vertebræ to the left, and when this movement of rotation had been rendered as complete as possible, the shelf of bone which projected from the left upper margin of the body of the 5th lumbar vertebra served to support the partly displaced 4th lumbar vertebra. In this joint, then, besides a partial forward displacement or spondylolistheris, a partial lateral displacement was also permitted.

It was apparent that this form of labour necessitated a powerful rotation of the thorax to the left upon the pelvis and 5th lumbar vertebra, that very much of the lateral flexion of the column also took place at this point, also that the trunk was more frequently flexed

to the right than to the left, and that the trunk was loaded to a certain extent during the performance of these movements. The lower of the two lateral dorsal curves was probably due to this frequent lateral flexion of the trunk obliquely to the right, and I considered that the upper lateral curve, with its convexity directed to the right, was compensatory and secondary to the lower one.

It was obvious, from the amount and variety of movement permitted between the bodies of the 4th and 5th lumbar vertebræ, that the articular processes and laminæ of these vertebræ must have undergone very considerable modifications. On examining the posterior aspect of the column, I found that the interspinous and supraspinous ligaments were very dense and strong, and, at the same time, remarkably pliant, so that they did not oppose any obstacle to extreme flexion and extension of the column. The spinous processes were large and broad, and, though deep, they were not so deep as they are in labourers who carry loads upon the head or shoulder. They also allowed of very complete extension of the lumbar spine. The spinous process of the sacrum was large and prominent, and in complete extension the spine of the 5th lumbar vertebra rested upon it.

On cutting into the interspinous ligaments connecting the 2nd, 3rd, 4th, and 5th vertebræ large synovial cavities were found in their substances, so that the interspinous ligaments formed strong elastic capsules, which connected the opposing surfaces of the spinous processes.

The cavity between the 2nd and 3rd spinous processes was larger than that between the 4th and 5th, while the cavity between the 3rd and 4th was very large, the opposing surfaces of bone being densely eburnated. This articular cavity extended forwards between the opposing laminæ. The spine and lamina of the 4th lumbar vertebra were then felt to be disconnected from the body, and on dividing the column in the middle line (fig. 2) it was seen that the spine, lamina, and inferior articular processes of the 4th lumbar vertebra were separated from the body, pedicles, and superior articular processes. The several parts of this vertebra in median section are shown in position in fig. 3. The upper surface of the lamina was eburnated. The fibro-cartilage between the 4th and 5th vertebræ was of normal thickness, and though it allowed of pretty considerable forward displacement of the 4th vertebra, especially when the column was flexed, it also allowed of its complete replacement when the column was completely extended. A small articular cavity was present in the substance of the cartilage. Though the intervertebral foramina were encroached upon, the nerves contained in it were not compressed. It was evident that at one time during the labour the thorax had been flexed on the pelvis, and that at another the column had been very forcibly extended. Besides articulating with the under surface of the lamina of the 3rd lumbar vertebra, the upper surface of the lamina of the 5th lumbar also articulated with the eburnated under surface of the pedicle and superior articular process of the 4th lumbar, and with a flattened eburnated facet on the under surface of the inferior articular processes of the 3rd lumbar vertebra (see figs. 2 and 3).

The facet which had originally existed on the inferior articular process had been completely altered in form by its extension upwards to the upper margin of the lamina. The articular surface was convex transversely, and looked forwards and very slightly outwards. This articular surface was continuous around a right angle with the eburnated upper surface of the lamina.

The superior articular processes of the same vertebra, which were connected to the pedicle, were considerably increased in depth and altered in form. The articular surface, regarded as a whole, looked backwards and inwards, but the anterior limit of this facet had been continued inwards and then slightly backwards, terminating in an irregular margin. By this means, the concavity of the anterior part of facet looked backwards and even slightly outwards. The upper extremity of this process was flattened and eburnated, and fitted into a deep depression which it had worn for itself in the pedicle of the 3rd lumbar vertebra. The under surfaces of the pedicle and superior articular process were flattened and eburnated, and articulated with the superior articular processes of the 5th lumbar and with the lamina of the 4th. The inferior articular processes of the 3rd lumbar were elongated. Their articular surfaces were also much increased in area. They were convex transversely, and in front were directed forwards, while posteriorly they looked outwards. It was quite obvious that the increase in the area of their articular surfaces was the result of the excavation of the pedicle of this vertebra by the pressure exerted upon it by the extremity of the articular process of the vertebra below. The under surface of this articular process (the inferior of the 3rd lumbar) was broad, flat, and eburnated, and it articulated with the upper surface of the lamina of the 4th lumbar vertebra and with the flattened upper extremity of the *superior articular process of the 5th lumbar*. The superior articular process differed but slightly from the normal.

The superior articular processes of the 5th lumbar were very thick and strong. Their upper extremities presented large flat semilunar eburnated facets, which articulated with the under surface of the pedicles of the 4th lumbar, and with the lower flattened extremities of the *inferior articular processes of the 3rd lumbar*. Its articular surface had been very much increased in depth by the excavation of its lamina by the extremity of the inferior articular process of the 4th vertebra in extreme and forcible extension of this portion of the column. The surface was concave transversely, and was directed backwards, its posterior part being directed inwards.

The articular surfaces on the articular processes of the last lumbar and 1st sacral vertebræ were increased in area in a similar manner, but to a much less extent.

I have described all these changes in detail for reasons which will be obvious. Examining the articulation of the last lumbar vertebra and sacrum, and the form of the several parts of the sacrum, it is seen that the movements that took place between these bones were those of considerable flexion and extension. It is probable that both these movements were exerted with very considerable force, especially that

of over-extension, since the spinous process of the sacrum and that of the last lumbar vertebra were thick and dense. The form and density of these processes, if examined alone, might have led one to imagine that the subject had been a labourer who carried loads upon his head or shoulder. An examination of the curve of the front of the sacrum, and of the condition of the fibro-cartilage between the sacrum and last lumbar vertebra, at once excludes this possibility. Therefore, we may safely conclude that movements of flexion and considerable extension took place between these bones, also that the latter movement particularly was carried out with considerable force.

If we examine the connections of the 3rd, 4th, and 5th vertebræ to one another, we gather, from the condition of the fibro-cartilages, the connections of the spinous processes, and the deep excavation of the pedicles and laminæ by the extremities of the articular processes, that movements of flexion and extension took place freely and frequently between these vertebræ, and that the movement of over-extension was carried out with much force.

We also see that, while in the 3rd and 5th vertebræ the movements of loaded over-extension, if I may so express myself, have only resulted in a considerable excavation of the pedicles of the upper vertebra and of the laminæ of the lower, in the case of the 4th vertebra the upper articular processes of the 5th lumbar vertebra and the lower articular processes of the 3rd lumbar have by this process of gradual excavation completely severed the spine, lamina, and lower articular processes from the remainder of the vertebra, *and articulated with one another.* I have already described in previous papers other examples of this process of section of vertebræ by pressure, but in those cases the last lumbar vertebra was the one always affected.

An examination of the altered form of the surfaces on the adjoining articular processes of the 3rd, 4th, and 5th vertebra shows that a very considerable amount of rotation took place between these vertebræ. After the division of the 4th lumbar vertebra into two parts by the pressure exerted upon it by the articular processes, a new joint was formed which admitted of extremely free rotation. It was formed *above* by the under surface of the spine and lower articular processes of the 3rd lumbar vertebra and by the excavated inferior surface of the pedicle of the 4th vertebra, and *below* by the spine and lamina of the 4th and the superior articular processes of the 5th vertebra. These opposing surfaces were densely eburnated and polished, and were connected by a loose elastic capsule. As we have already seen, the fibro-cartilage between the 4th and 5th vertebræ was very thick and elastic, and readily allowed of very considerable rotation of one vertebral body upon another.

The margins of both *sacro-iliac joints* were slightly irregular, and the upper portions of the intervening cartilages had been divided and partly removed. These joints allowed of considerable flexion and extension movements, the latter being more freely permitted. At the same time it was apparent that during these movements the trunk had been moderately but not excessively loaded. The left joint showed more change than the right.

In the *left hip joint* the area of the upper margin of the articular cavity immediately below the anterior inferior spine was extended by the deposit of bone and cartilage upon it. The head and neck of the femur presented in a moderate degree those flexion changes I have already figured and described ("The Causation and Pathology of the so-called Disease Rheumatoid Arthritis and of Senile Changes"). The movement which had been performed habitually in this joint appeared to have been one of oblique rather than simple flexion. Here again it was obvious that during the performance of these movements in this joint the body had not been excessively loaded, though it had been considerably so.

The *right hip joint* showed very slight flexion change.

The lungs & bronchial glands contained much black pigment.

I will now state the conclusions which we are able to arrive at from the examination of the bones and ligaments of this subject.

We are at once able to exclude all those forms of labour which I have already observed and described, namely,—

(*a*) Those in which the load is carried upon the head or upon the shoulder. In this group, the centre of gravity of the load and trunk corresponds in its position in relation to the pelvis to that of the unloaded trunk.

(*b*) Those in which the load is carried upon the back of the head, neck, and trunk. In this group the centre of gravity of the loaded trunk falls in front of the normal.

(*c*) Those in which the load is carried in the hands, as in the milkman, and those which I have not yet described, in which the load is carried more apparently in front of the trunk, as in pregnant women, women carrying children in their arms, and in occupations in which a load is supported in the front of the trunk. In this group, the centre of gravity of the loaded trunk falls well behind the normal.

It is apparent that this man has for very many years, very probably during the whole of his vigorous adult life, performed the same form of labour, and that the labour was peculiarly routine in character. By the labour being routine, I mean, that it consisted of certain successions of movements, each succession differing from the preceding one in no important particular.

It is also obvious that the various movements which made up a succession were very different in character, and that in all of them the trunk was loaded to a moderate extent. In some of

them the load or force resisted was relatively great, while in others it was relatively small. For instance,—

(*a*) The movements of over-extension of the spinal column were very free, and had been carried out with very considerable force, so that we may conclude that, during the over-extension of the trunk, the load lay behind the vertical plane of the trunk so that the combined centre of gravity of trunk and load fell behind that of the normal trunk.

(*b*) Also, during the movement of flexion of the thorax upon the pelvis the load lay in front of the body, the common centre of gravity of load and trunk lying in front of that of the trunk alone. During the movement of flexion the load did not produce the same marked result as it did in the movement of extension, therefore it was practically not so heavy.

(*c*) Also, besides the movement of simple flexion, those of oblique flexion very frequently occurred. These were in the large majority of successions directed to the right, though the oblique movement to the left was by no means infrequent.

(*d*) The thorax and load were rotated to the left with very considerable force, and to a very great extent. The force exerted in performing this rotation of the trunk must have been very great, therefore it is extremely probable that the rotation was produced in part by the impetus given to the body by a moving load which rotated around the same axis as the trunk. The load would therefore pass from the front of the trunk to the left of it and then well behind it. The first and last of these movements we have already observed.

(*e*) While the trunk was flexed upon itself, the pelvis was flexed upon the left thigh, which was rotated outwards to a considerable extent. Very much more strain was exerted upon the left than upon the right hip joint.

(*f*) Very great resistance was experienced by the hand and fore-arm when forced forwards with very considerable force. This movement took place when the trunk was flexed upon itself and upon the left thigh.

(*g*) The fore-arm, loaded by a considerable weight, was then flexed upon the upper arm.

(*h*) The right upper extremity and load was flexed very considerably at the shoulder-joint.

(*i*) The small extent of angular movement permitted in the right elbow-joint, as compared to that of the left, and the knowledge we already possess that the load, while somewhat rigidly attached to the trunk, was carried in a semicircle around it, suggests that the load could not have been supported directly by both hands, but indirectly by means of some rigid support, as, for example, a load of any heavy material supported upon a spade or shovel, the handle of which was held in the right hand. Putting together the several movements that formed this succession, I concluded that during the whole of his active life this man had been continually occupied in shovelling some material which was very coarse, in the sense of offering resistance to the passage of the spade through it, and also very heavy, from the level of the ground, and throwing it to some considerable distance behind him and to his left.

The occupation of filling carts with gravel or coal then appeared to me to be the most likely, yet I was doubtful, from an observation of such labourers, whether such an occupation would give the very extensive and free rotation of the thorax which this skeleton apparently indicated.

As I have been so frequently unsuccessful in my attempts at obtaining the labour-history of the individual, during his active life, from the authorities of the institutions from which our subjects come, I had neglected to write for information in this case. I then did so, and the medical officer very kindly informed me that his last occupation had been that of ship-keeper. By inquiring I then found out that among the men who were most frequently employed as shipkeepers were old ship's-carpenters or trimmers, who had served for a long time and who had got good characters as being steady and good workmen. Now a ship's carpenter would not have suited my purpose at all, for the reason that he is practically a jack-of-all-trades, and is not occupied in a sufficiently routine manner. However, the trimmer was just the man I wanted. As the reader is possibly as little familiar with the habits of this class of labourer as I was, I will briefly sketch out their form of labour. In the coaling of the ship the trimmer is a very important individual, for it is his duty to arrange the coal, after it has been thrown down, in such a manner that the ship's

equilibrium may be stable. This requires very considerable skill, as many ships required to be trimmed in a particular manner, and this manner may be varied under different circumstances. Consequently the labourer devotes himself to this peculiar form of labour and does nothing else. He commences it at an early period of his life, and he must necessarily be very powerfully built as he has to shovel the coarse coal and to throw it enormous distances, and the force exerted in doing this is very great indeed.[1]

I think that if the reader has followed me step by step through the several anatomical details, he will agree with me as to the correction of the conclusion at which I have arrived. I hope that I have not neglected to explain any of the anatomical details which, though familiar to me from continually examining, observing, and analysing them, may not be so patent to those who have not devoted so much time and attention to the subject.

Before leaving the consideration of this case, I will call particular attention to one or two details which are of special interest.

In those forms of labour in which a heavy load is borne upon the rigid trunk, and the weight of the load and trunk is transmitted to the pelvis through a vertical median plane, I have shown that the constant pressure exerted by the inferior articular processes of the 4th lumbar vertebra, and by the superior articular processes of the sacrum upon that portion of the arch of the 5th lumbar vertebra which lies between their extremities, may cause its partial or complete section. The posterior segment which results from this section consists of spine, lamina, and inferior articular processes, while the remainder of the vertebra forms the anterior segment. In such labourers no obvious movement of rotation around a vertical axis takes place between the 5th lumbar vertebra and the sacrum. Now, in the case I have described in this paper, the 4th lumbar vertebra has been divided in a very similar, though not in the same identical, manner, and for this reason that the

[1] I must here express my thanks to Messrs Thistle, Jewell, and Jordan for their kindness in obtaining for me information of the habits of these labourers.

occupation of the individual required that the thorax and load be forcibly rotated upon the pelvis.

Under such circumstances, it is obviously advantageous that this rotation should take place as low down as possible in the column. It is impossible for this movement of rotation to take place between the 5th lumbar vertebra and sacrum, owing to the firm connection of the former bone to the pelvis, so that the next lowest possible seat of chief rotation must be the articulation of the 4th with the 5th lumbar vertebra. It is apparent that the normal formation of the articular processes of these vertebræ, would not allow of any very extensive rotation, consequently the form of the processes and the direction of their articular surfaces require considerable modification.

The examination of the lumbar spine in my case showed that, before the arch of the 4th lumbar vertebra had been cut through, the undivided 4th lumbar vertebra rotated freely upon the subjacent vertebra, and the forms of the articular surfaces on the opposing articular processes had undergone very considerable alterations, so as to allow of this exaggerated movement.

Owing to the vertical pressure exerted by the extremities of the upper articular processes of the 5th vertebra upon the arch of the superjacent vertebra at the bases of the facets on its inferior articular processes, during over-extension of the spine, and owing also to the transverse cutting movement exerted by the same processes during the violent rotation of the column, the articular surfaces on the inferior articular processes of the 4th vertebra were gradually extended upwards at the expense of the arch of the vertebra. A similar process produced an increase in the area and direction of the facets of the superior articular processes of the 4th vertebra, also at the expense of the vertebral arch. The arch was finally completely cut through in two points by the rapid destruction of its lower margin, and the more gradual removal of its upper margin. The less rapid destruction of the upper margin was due to the less extensive rotation which took place between the 3rd and 4th lumbar vertebræ.

After the 4th lumbar vertebra had been divided into two distinct parts, the anterior of which comprised the body, pedicles, and superior articular processes, and the posterior, the remainder

of the vertebra, rotation then took place between the body and excavated pedicle of the 4th lumbar vertebra, the inferior articular and the lower margin of the spine and lamina of the 3rd lumbar above, and the body and superior articular processes of the 5th vertebra, and the upper margin of the spine and lamina of the 4th vertebra below. I have frequently seen the earlier stage of this condition resulting from over-extension and excessive rotation in bodies I have dissected of subjects affected with hip disease in early life, and in which there had been much shortening, on account of the femur becoming ankylosed to the innominate bone at an angle, also in cases of united or ununited fracture of the neck of the femur, in which there was considerable shortening. In such cases it becomes necessary, in order to maintain the equilibrium during walking, that the pelvis and shortened limb be rotated very forcibly upon the upper part of the trunk. The amount of pressure-change observed in this portion of the lumbar spine varies directly with the force and extent of this rotation.

I have already, in a previous paper in the *Trans. Path. Soc.* ("Pressure-Changes in the Lower Part of the Spinal Column"), referred to work done by Professor Neugebauer of Warsaw, in connection with the divided condition of the vertebral arch of the 5th lumbar vertebra, and in it I criticised the views which he put forward as to its causation, as well as that of spondylolisthesis. He has, I find, described two cases,[1] or rather specimens (for he only describes a portion of the body, and makes no mention of any change observed in the rest of the skeleton), in which the 4th lumbar vertebra was divided into two parts, in a manner which, as far as one can judge from his diagrams and descriptions, appears to resemble the condition I have described in this paper. As in the case of the 5th lumbar vertebra, so also in that of the 4th, he considers that the division of the vertebral arch must be the result of one of two causes, either that the arch had been fractured in two points and the fragments have not united, or that the several bony centres had never united to render the arch complete. I will quote his own words, "Die

[1] "Aetiologie der sogenannten Spondylolisthesis," *Archiv f. Gynækologie*, Bd. xx. Heft 1; and "Ein zweiter Fall von sogenannten Spondylolisthesis am vorletzten Lendenwirbel," *Archiv f. Gynækologie*, Bd. xxi. Heft 2.

Ursache der letzeren" (namely, the divided condition of the arch) ist in beiden Fällen zweifelhaft (Fractür oder congenital begründete Lysis ?—letzere angesichts der grossen Analogie der zahlreich beobachteten Fälle bedeutend wahrscheinlicher). For the reasons which he gives for ascribing this condition to non-union of the bony centres, I must refer the reader to his writings on the subject. I will not express any opinion on the two cases which he has described, beyond saying that the conditions of the 4th lumbar vertebra, which he illustrates, seem almost identical with those I have described, and, as I stated, concerning the cases of divided 5th lumbar vertebra which I dissected, so I would assert of this example of divided 4th lumbar vertebra, *that the causation of the condition is pressure and not fracture, or a non-union of bony centres.*

In Professor Neugebauer's cases, as in mine, there was a certain amount of forward displacement of the 4th lumbar vertebra, but I think that I have already sufficiently accounted for it, and an examination of figs. 2 and 3 renders the mode of its occurrence at once obvious.

Although I altogether disagree with Neugebauer in his views upon the causation of the conditions alluded to, I must congratulate him on the many very interesting observations he has made, and the care with which he has worked out details connected with them.[1]

Another point I will particularly allude to is the *very important part played by the thickened and branched fringes of synovial membrane and ligament, additamentary bones, &c., in pressure-changes.* I have described several instances illustrating their functions in this and previous papers. They serve, as do the alterations in the area and form of the opposing surfaces of bone, to render a joint more secure under the influence of great strain, whether exerted at one time or repeatedly, and they are especially abundant when this strain has been sufficient to cause partial or complete displacement of the opposing articular surfaces. These formations differ in their

[1] Professor Sir W. Turner has described several cases of want of union of the neural arch with the body of the 5th lumbar vertebra, which he ascribes to imperfect development. See his *Report on Human Skeletons, Challenger Reports*, vol. xvi., 1886.

causation in no manner from the remainder of the changes that ensue as the result of pressure; I am alluding to them here, as I described them but very briefly in my paper "On the Causation of the so-called Disease Rheumatoid Arthritis and of Senile Changes," *Trans. Pathological Society*, 1886.

The abundant ingrowths from the synovial membranes and ligaments of a joint serve to fill the often considerable interval between displaced bones, and in this manner they render the movements between them more secure. The more such a dislocated joint is used, the more abundant are the branched processes of synovial membrane which fill up the gaps, and the marginal deposit of bone or the additamentary bones which develop in contact with the margin of points of bone, forming part of the new socket. I do not think that I can give a better illustration of this, than by briefly describing the functions they exert in a well-marked case of pressure-change in the shoulder-joint, which condition is usually described as rheumatoid arthritis affecting that joint.

In such a joint, as is well known, the head of the humerus articulates with a cavity which is formed by the upper part of the glenoid cavity and the under surfaces of the outer end of the clavicle, the acromion, and the coracoid process. These bones must undergo changes in form, so that they may serve their new purpose of accommodating the displaced head of the humerus during the various movements of the upper arm.

Besides an alteration in their surfaces, a deposit of bone takes place upon the margin of these several bones, in order to increase their breadth, or new bone is formed in masses in the soft parts immediately adjacent to their margins, for the same purpose, and these new formations are usually called *additamentary bones*. The soft parts which intervene between the bones forming the socket for the head of the humerus must become changed in a similar manner. Portions of the intervals are filled up by ligamentous tissue, and an abundant growth of branched processes takes place from the inner surface of the synovial membrane. This last formation serves as a very useful capsule, as it fills up the gaps between the bones during their movements and accurately following the surface of the humerus, since the cavity of the joint is a vacuum. By these means the movements

permitted in the dislocated joint are rendered much more free and secure than if these structures were not present. They are seen to serve a similar purpose in some loose arthrodial so-called false joints formed by the fractured extremities of a long bone with one another.

Lastly, I will briefly describe the following instance of the manner in which the ligaments of a joint may, after a deformity necessitating some alteration in the original arrangement of its articular surfaces, extend in between the bones and fill up any gap left between them, serving the same purpose as do the fibro-cartilages in the knee-joint. This case also shows remarkably well the very considerable alteration in form which the upper extremity of the femur undergoes when its area of articular surface is increased by the formation of articular cartilage and bone on the margin of its original surface.

The subject was one that came into the dissecting-room of Guy's Hospital. I concluded at once, from an examination of the upper extremities of the thigh bones, that the right leg was considerably shorter than the left, and that this shortening had occurred during early life. Measurement of the lower extremities then verified both conclusions. The right leg was an inch and a quarter shorter than the left. The right femur was but little shorter than the left; the greater part of the difference was due to the fact that the right lower leg was considerably shorter than the left. There was no sign of fracture or injury of the bones, and the only apparent probable cause was infantile paralysis. By this time the brain had been removed from the body, and the spinal cord was too much decomposed to show any change on section.

Figs. 4 and 5 represent the anterior and posterior surfaces respectively of the upper extremity of the right femur, and from these two diagrams the reader will at once see that the original articular surface of the head has been extended outwards above and behind, and not, as in the ordinary flexion pressure-changes, outwards and downwards over the front of the neck of the femur. This shows that the pelvis had been rotated very considerably about an antero-posterior axis during progression.

Beyond the margin of the articular surface of the head of the left femur three masses of bones are seen covered by synovial

membrane. They served to transmit pressure during certain movements of the hip-joint, but not with sufficient frequency to necessitate their being covered with articular cartilage.

The posterior surface of the extended articular surface of the head ended abruptly by a free margin, which was separated by a considerable interval from the surface of the neck.

The acetabular cavity was increased in depth by the deposit of bone and articular cartilage upon its margin. This process had been a very gradual one, as the cotyloid ligament was not in the slightest degree separated from the margin of the cavity.

A small interval existed between the back part of the head of the femur and the lower part of the acetabular cavity. This gap, which varied in extent with the various movements of the joint, was occupied by a large movable crescentic fibrous mass, whose surfaces were covered by synovial membrane, whose thick base was attached to and continuous with the cotyloid ligament, and whose free margin consisted of innumerable branched processes of ligament. It was practically identical in structure with the branched processes of synovial membrane already alluded to, and a little consideration will show that it developed in the same manner, and served a similar purpose.

As in the case of the interarticular fibro-cartilages in the knee-joint, it was not fixed, but accommodated itself to the varying movements of the head.

The head of the left femur showed but slight changes, and these were such as are usually present under the circumstances. I will not describe its condition further, as I am merely making use of the case with the object of illustrating the fact *that the synovial and ligamentous fringes, like the additamentary bones, exist to perform certain useful functions as much as do any of the structures making up the original articulation.*

I will take this opportunity to correct three printer's errors, which I have observed in the last page of a paper entitled "Some Variations in the Human Skeleton," in this *Journal*, 1885, p. 404. In two cases the conjugate of the *brain* is described, instead of the conjugate of the *brim* of the pelvis, and in the ninth line from the bottom, the transverse diameter of the brim is described as being $8\frac{1}{4}$ inches instead of 5.

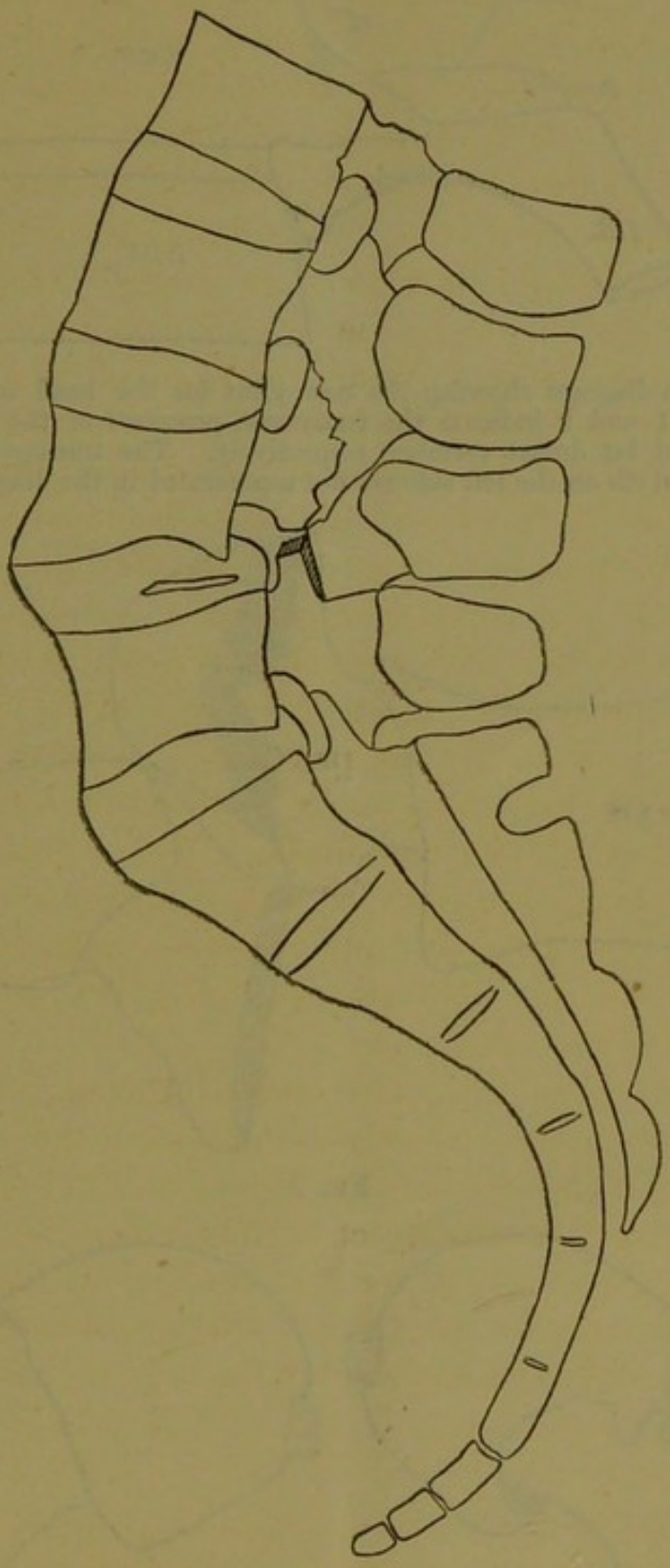

FIG. 2.—Vertical Median Section of Lumbar and Sacral Vertebræ.

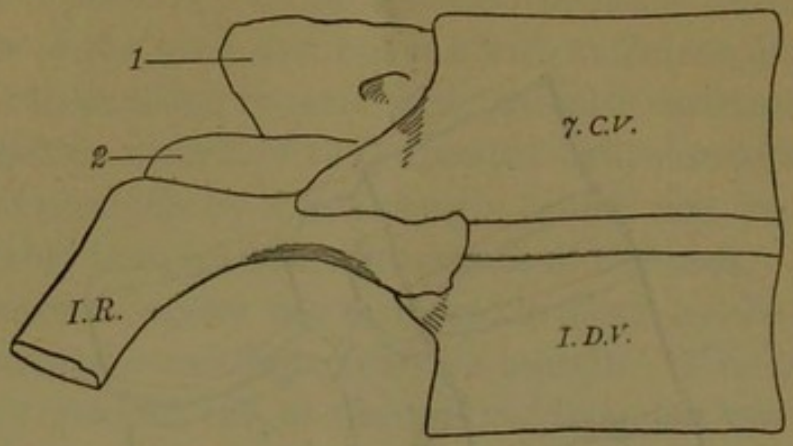

FIG. 1 is a diagram showing the new joint for the head of the first rib. 1 and 2 indicate the transverse processes of the 7th cervical and 1st dorsal vertebræ respectively. The transverse process and 1st rib on the left side are not represented in the diagram.

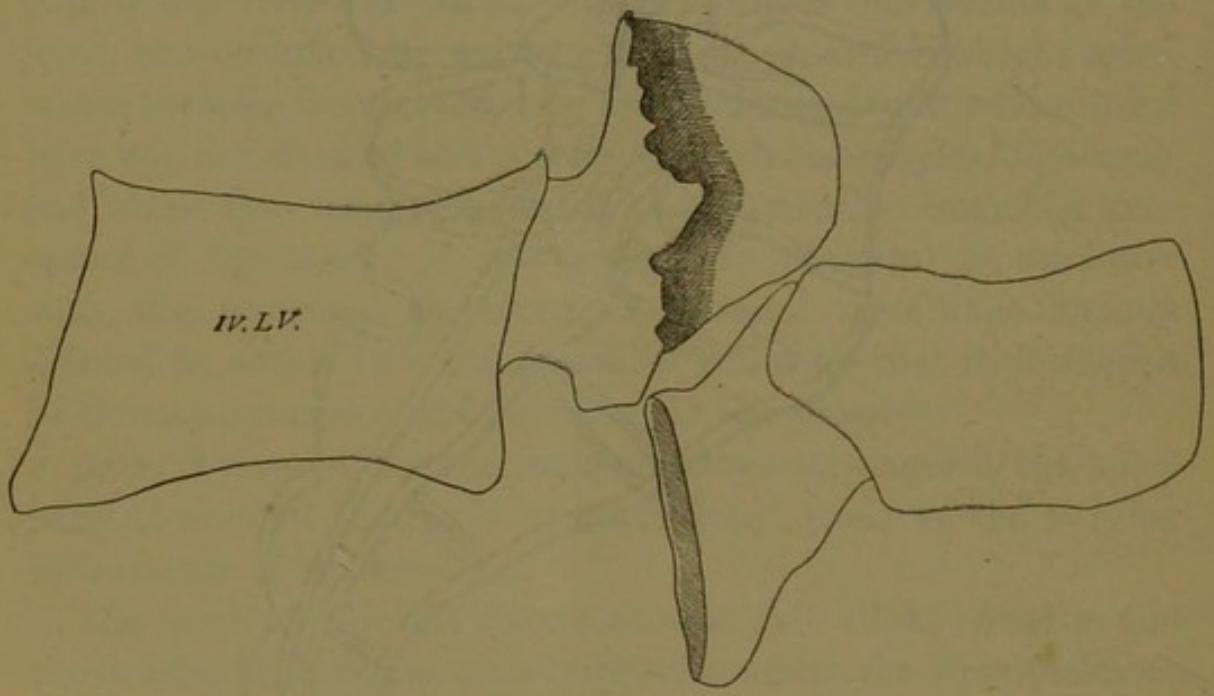

FIG. 3.

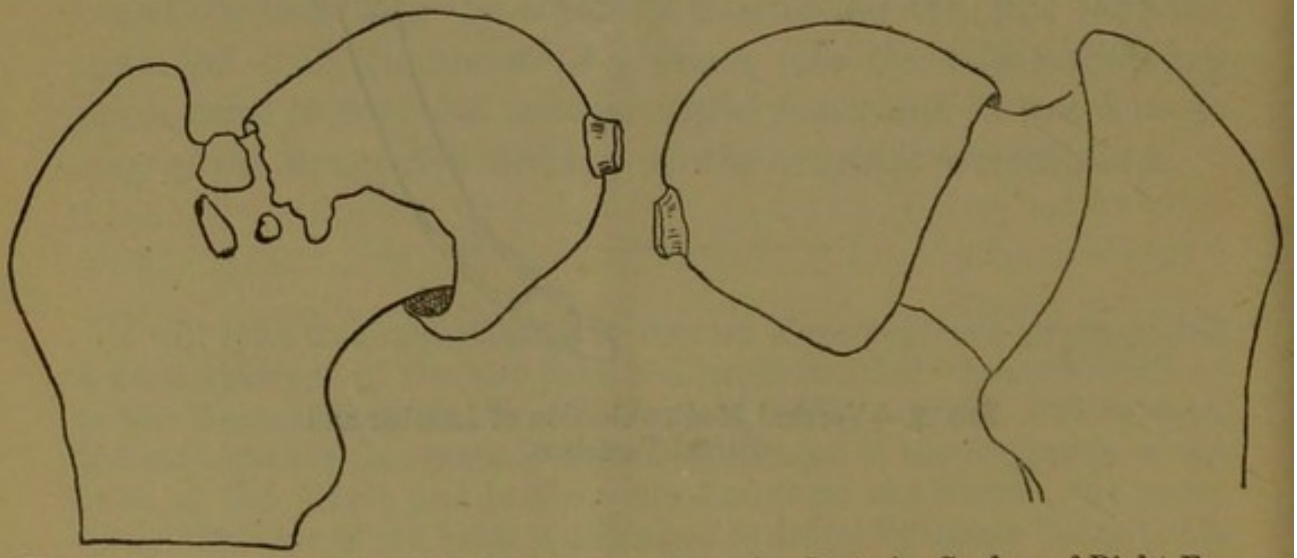

FIG. 4.—Anterior Surface of Right Femur. FIG. 5.—Posterior Surface of Right Femur.