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T H E S I S .

CHANGES WHICH THE THORAX UNDERGOES IN ITS ADAPTATION TO THE ERECT POSTURE IN MAN.

With

Notes on Fracture of Ribs due to Indirect Violence & Spinal Curvature.

BY

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I N D E X.

T H E S I S .

CHANGES WHICH THE THORAX UNDERGOES IN ITS ADAPTATION TO THE ERECT POSTURE IN MAN.

When searching for a subject for a Thesis, my attention was drawn by Professor Cunningham, to the remarkable similarity in general shape, between the Thorax of the Orang (Pithecus Satyrus) and the human foetus.

This further suggested the idea that, underlying this general appearance, there might be found, by dissecting foetuses of various ages, and comparing the inclinations of their ribs to the vertebral column, the various curves of the ribs in the horizontal and vertical planes, the angles of the ribs and, in fact, all that takes share in the formation of the shape of the Thorax, with the corresponding things in the adult man and the monkey, there might be general laws which regulated the shape of the Thorax in all of them.

Obviously, the erect attitude in man may be assumed to be responsible for great changes in the shape of various parts of the body, in which changes the/

the shape of the thorax must necessarily be involved.

Again, the attitude and general mode of progression adopted by the Anthropoid ape suggested that shapes of various parts of the body and constituents of the body, including the shape of the thorax, would be found intermediate between that which holds in the human foetus, and that which is found in the adult man. The problem, therefore, became the following:-

Can it be shown, that the shape of the various parts that constitute the shape of the thorax, is intermediate between that of the foetus in utero, and the adult man, seeing that the monkey habitually adopts an attitude, intermediate in position between that of the foetus in utero, and the adult man; and, further that, as the attitude of the monkey is further removed from the adult man, than it is from the foetus, that the shape of the monkey's Thorax is nearer that of the foetus than it is that of the adult man?

This being the problem, measurements were taken from formalin injected specimens and Museum preparations. Five foetuses were injected with formalin and then dissected and measured. Two of them were full time foetuses, two, six months, and one between 5 and 6 months.

As/

As an example of the Anthropoid ape, a formalin injected red orang (Pithecus Satyrus) very kindly lent to me by Professor Cunningham, was taken and measured, and permission was given to me by Professor Cunningham, to obtain the sanction of Dr.Waterston to measure and take models of the formalin-injected subjects in the Dissecting Room.

Models of the various Thoraces measured, have been made, and have been sent in for examination.

Casts were first made of gelatine and then models were taken off the casts.

In the investigation, the shape of the Thorax will be considered generally, and then in detail.

The erect attitude assumed by Man brings about a great variety of changes in the shape of bones, the attachment muscles, the comparative length and position of the upper and lower extremities, etc., all these things react in producing changes in the shape of the Thorax. As a preliminary to the work, numerous measurements were taken on the disarticulated ribs. This gave a considerable amount of information about the curvatures of individual ribs, especially in regard to the curvature of each rib from its head to its angle.

There are, however, numerous difficulties in the way of obtaining complete sets of disarticulated/

disarticulated ribs.

Again, no conclusions can be drawn from these disarticulated sets, about the inclinations of the ribs to the vertebral column in the vertical direction, or the amount which the ribs pass backwards from the vertebral column, and thus what share they take, as we shall afterwards see, in the formation of the angle of the ribs.

Nor can one draw any conclusions about the crowding together, or otherwise of the ribs, from the disarticulated sets - we shall afterwards see that this crowding together of the upper ribs, just beyond their angles, is a very noticeable feature in the monkey and the foetus.

GENERAL SHAPE OF THE THORAX.

The Thorax in the Adult Man is broader from side to side than from before backwards.(1) The Posterior wall is longer than the Anterior. The Maximum Transverse diameter is opposite the 8th or 9th Rib (2) and is largely owing to the forward projection of/

(1) Holden. Human Osteology, Philadelphia 1878.

(2) Cunningham. Text Book of Anatomy Osteology p.98.

The above photograph is that
of a foetus younger than 6 months
It is spoken of in the text, as
the Youngest foetus. It shows
the lateral compression, & is
a view taken, looking into the
inlet of the Thorax.

of the Thoracic part of the Vertebral Column into the Thoracic cavity.

In the foetus, the form of the Thorax differs from that of the Adult. It is laterally compressed. Its antero-posterior diameter is relatively greater than in the Adult.

In this respect the foetus shows a striking resemblance to that which is found in the Orang. In the Adult Man the backward sweep of the ribs from their heads to the angle leave deep furrows on either side of the vertebral column for the Erector Spinae muscles, and also allow for the expansion of the lungs backward to make up for the shortened antero-posterior diameter.

In the foetus and in the Orang, the Thorax is small in comparison with the abdomen. The hollows on either side of the spine are comparatively shallow. Moreover, in both foetus and Orang there is a considerable difference in the inclination of the ribs to the Vertebral Column, from that in the Adult Man. (1).

In the newly born child, changes in form take place, dependent on the expansion of the lungs, during/

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(1) Humphry. Treatise on Human Skeleton. Cambridge 1858. Chap. Thorax.

during the subsequent growth of the child. The further expansion of the Thoracic cavity in a Transverse direction is correlated with the assumption of the erect posture, and the use of the fore limbs as prehensile Organs.(Cunningham). (1)

Symington (2) says that "in the newly born child the transverse diameter of the Thoracic cavity is about twice that of the antero-posterior, while in the adult it is three times greater."

He evidently here measures the distance of the Antero-posterior diameter from the front of the Vertebral Column to the Anterior Chest wall. Symington further remarks, that the transverse diameter of the Thoracic Cavity does not attain its Maximum excess over the Antero-posterior until near adult life.

On looking into the Thoracic Cavity of the Orang from which the viscera have been taken, the general shape strikes one as being very similar to that of a foetus. The Anterior Chest wall appears to be shortened, and the Posterior lengthened.

The upper six ribs appear to be crowded together, as in the foetus. The whole effect seems as if it might have been produced by doubling up the body/

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(1) Cunningham. Anat. (Osteology, p.29.)

(2) Anatomy of the Child Edinburgh 1881.

body of the monkey into the position of the human foetus in utero.

Owen (1) (Anatomy of Vertebrates) remarks that "the whole thorax appears to be squeezed in laterally, and also to be encroached upon by the contents of the abdomen, as in the foetus."

CAUSES WHICH INFLUENCE THE SHAPE OF THE THORAX.

By the assumption of the erect attitude in man, the centre of gravity of the body is thrown backwards (2)

In man the Thorax is pressed backwards to assist in balancing the body in the erect posture. It is shortened also, to permit of a free range to the flexion and extension of the trunk. The weight of the body, and thus also the weight of the Viscera in the chest, is redistributed. This helps to cause a change in the shape of the Thorax. This posterior projection brings the ribs nearly to a level with the spinous processes, and causes that flatness of the back and that ability to lie at ease upon the back which/

(1) Anatomy of Vertebrates.

(2) Quain's Anatomy Vol.II. Part I.

which is peculiar to man. It also increases the capacity of the chest, and makes amends for the comparatively short Antero-posterior diameter of the Human Thorax.(1)

The centre of gravity of the whole body (Adult) is at a point just above the sacro-lumbar angle, and exactly over the mid-point of a line drawn between the heads of the femora.(2)

The centre of gravity of the human trunk and body respectively, in their normal erect positions, are situated, the former in the 9th Dorsal Vertebra, the latter in the interior of the canal of the 2nd Dorsal Vertebra.

By the term body, is meant the entire frame, trunk and limbs. Movements of the head, changes in the circulation of the blood, in the liver etc. slightly affect the position of the centre of gravity. In no animal can the centre of gravity be in these positions - it must be situated below the vertebral column. (3)

The erect position is here defined to be that in which the body is placed, when all the parts are/

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(1) Humphry.

(2) Treves. Surgical applied Anatomy 1884. Cassell & Co.

(3) Goodsir (Memoirs of John)

are arranged so as to occasion the least amount of exertion.

The upper extremities and the muscles attached to them (for purposes of gripping etc.) cause changes in the shape of the Thorax.(1)

The arms in man have to move in all directions, and especially outwardly, and to this end are kept wide apart by the clavicles. In quadrupeds proper, they only serve for locomotion, fall in a parallel way downwards, and remain apart. In this way the clavicle disappears and the Thorax becomes flattened sideways. Monkeys(2) in this respect, hold an inferior position to quadrupeds a superior one to man. The Lemurians, the Cebians and the Pithecians, have the Thorax compressed laterally, the Anthropoid Apes rather from before backwards.

The ribs show a tendency to decrease in number in Man, and also fewer of them are attached to the Sternum. This change is shown by the attachments of the Serratus Posticus inferior and the Latissimus Dorsi.(3)

In the infant while still unable to walk, the/

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(1) Wiedersheim. Bau des Menschen Thorax. Freiburg 1902.
(2) Topinard. Anthropology. Trans. by Robt.H.Bartley London 1890.
(3) Wiedersheim Cet. loc.

the large proportional size of the head, amounting to nearly a fifth of the whole body, the comparative straightness of the Vertebral Column, or absence of those curves, which characterise the spine of the adult, the shortness of the lower limbs, and the incompleteness of their structure, all contribute to render the assumption of the erect attitude by the child, for a time, difficult and insecure.

The middle distance (1) between the vertex of the head and the sole of the foot, in an infant, is situated somewhat above the umbilicus, while in the adult, it is generally at the upper border of the pubes or even lower, in some part of the symphysis.

In the child also, from the large dimensions of the head, and upper part of the body, the centre of gravity is carried to a considerably higher point than in the adult.

As a consequence of the above, one would expect to find the child's chest modified from that of the Adult.

In the foetus, the small size of the pelvis and lower limbs compared with the head, during the first months of foetal life, causes the middle point of the body to be situated higher at that period, than afterwards. At about 3 months it is a little above the lower end of the sternum. Before this it /

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(1) Quain's Anatomy 10th Edition 1890.

it is higher still. At 7 months it is just below the lower end of the sternum. At birth it is a little above the umbilicus.(1).

In this position of the middle point of the body, there will be noticed a point of similarity between the foetal and the quadrumanous skeleton. From the above observations it will be seen that the Centre of Gravity in the foetus will be carried to a higher point still than in the young child.

Now an adult man, standing upright, with his arms at his side, is evidently in a position of equilibrium - stable equilibrium. Stable equilibrium is the truly practical kind of equilibrium, of which there are three kinds - stable, unstable and neutral.

To illustrate this, suppose we have a loaded sphere placed on a flat surface, as in the figure I. If the load be a piece of lead, say, placed at A. then in Fig.I. we see that the weight W. of the sphere, acting at O, the centre of the sphere (the sphere is supposed to be uniform) and the weight W of the lead placed at A; both act in the same/

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(1)Humphry. Quain.

fig I

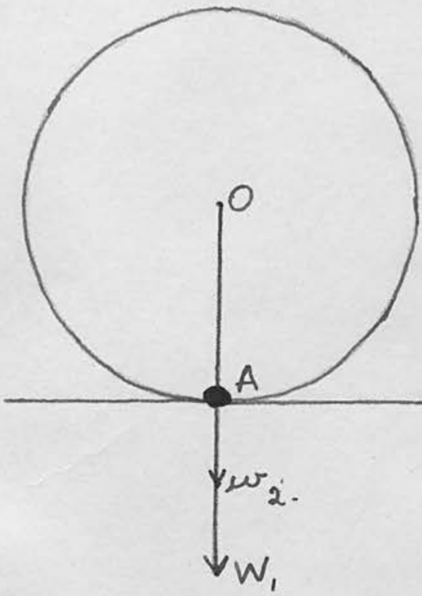
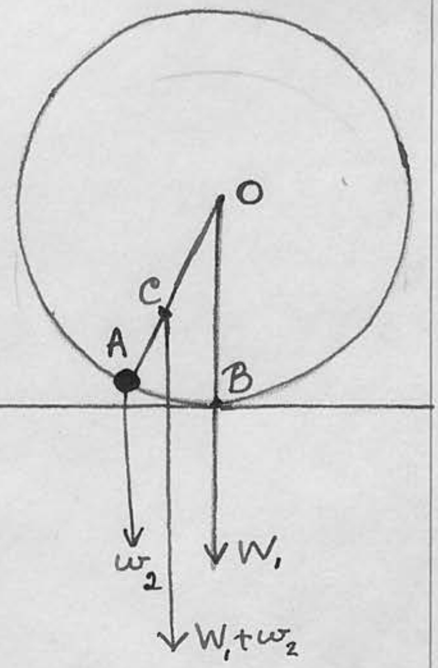


fig. 2.



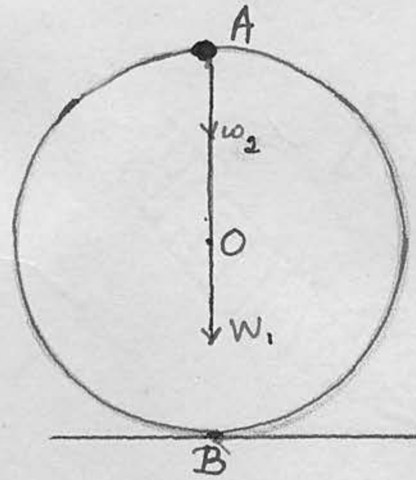


fig. 3.

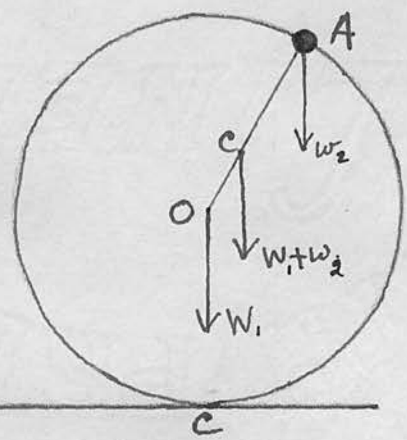


fig. 4.

same vertical line which passes through A. the point of support of the sphere on the plane surface.

Now, if we slightly displace the sphere to the position in the Fig.2, then we see that the weight of the lead, and the weight of the sphere, act in different parallel directions. Their resultant is a weight equal to the sum of their weights $W_1 + W_2$, acting at some point, C in the line joining AO such that -

$$\frac{AC}{CO} = \frac{W_1}{W_2}$$

Thus the resultant force on the sphere acts in the vertical line through C, which line does not pass through B, the point of support of the sphere.

Therefore the sphere will tend to rotate back again, until it rests once more on the point A. The sphere is therefore said to be in a state of stable equilibrium.

On the other hand, if the load had been put at A. on the top of the sphere, as in Fig.3, Then with a slight displacement into the position in Fig.4, we should get the state there depicted. In this case, the sphere would tend to rotate still further from the original position of rest it occupied in Fig.3.

In this case the sphere is said to be in a state of unstable equilibrium.

Applying this reasoning to the Adult Man and/

Child at Birth

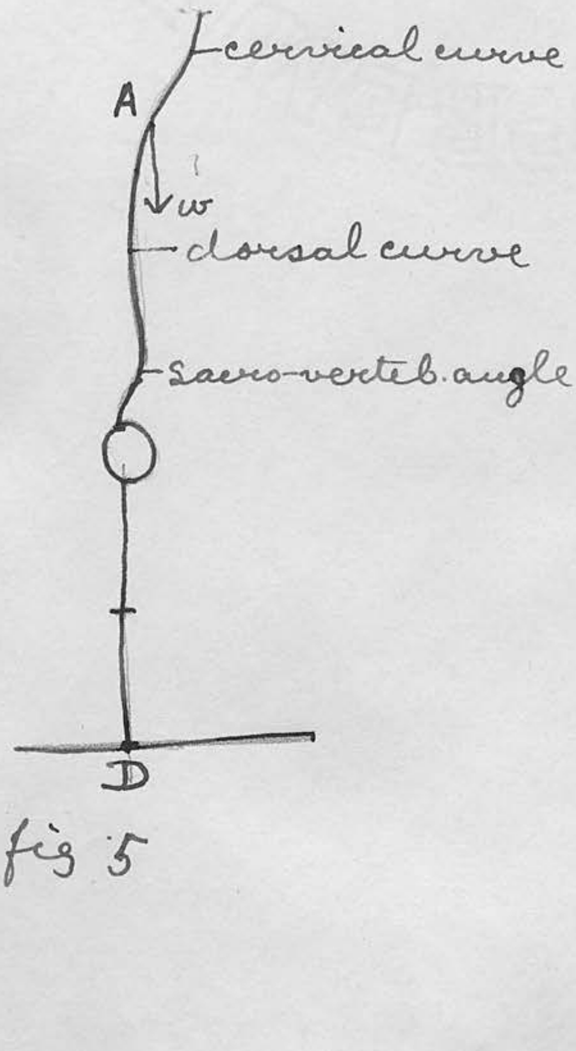


fig 5

Adult Man.

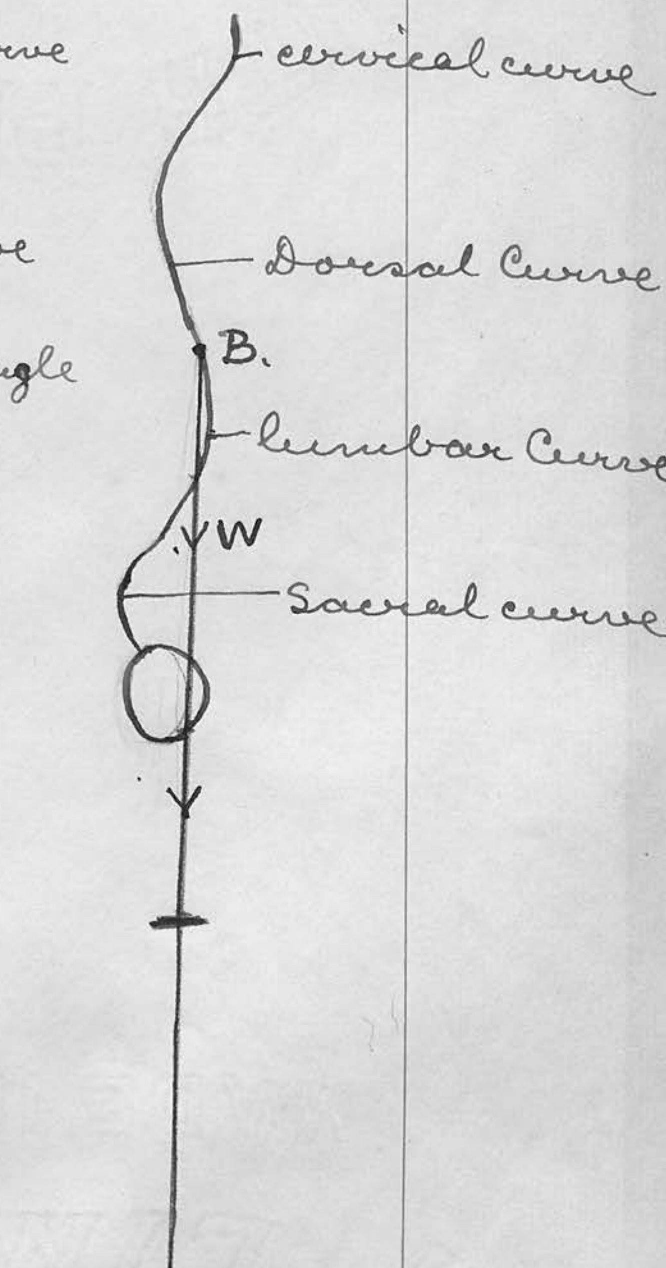


fig. 6.

and the infant, we get an explanation why the erect attitude is the natural one to man, and not the natural one to a young infant. In the Fig.6, we see that the weight W. of the whole body of the Adult Man, acting at its centre of gravity B. acts vertically down through the base of support of the man at C . Whereas, in the case of the infant, the weight w, acting at A. the centre of Gravity, a relatively higher point than in the Adult Man, does not tend to pass through the base of support at D., if the child be placed in the erect attitude, and therefore the child tends to topple forwards. In other words, the erect attitude in man, is the position of stable equilibrium for him, whereas it is one of unstable equilibrium for the young child.

Obviously, there is no use in applying this reasoning to the case of the foetus.

In man the feet are formed with a base which is large in proportion to his body, so that the centre of Gravity can be kept vertically over the base, a condition which is essential to his stability. The legs in their erect attitude are placed at right angles to the sole of the feet, and are therefore vertical when the latter are horizontal. The Centre of Gravity of the trunk being, as stated above, in the 9th Dorsal vertebra, the trunk would have a tendency to incline forward, and take the position of that of a quadruped, in which case the spine

would/

would then be horizontal; the upper part of the trunk being supported by the arms, the hands performing the duties of fore-feet.

But this is prevented by the establishment along the whole extent of the back of layers of powerful muscles, which tie the vertebrae together, two and two, three and three, four and four, and so on.

The tone of these muscles is such, that their normal tension produces a force which equilibrates with the weight of the trunk, acting at its centre of Gravity. When a man is standing on both feet, the base of support is the area of the two soles, together with the space included between them.

In the foregoing remarks on the state of equilibrium of Man in the erect attitude, nothing was said about the action of the muscles, when the erect attitude is assumed.

As a matter of fact, it is the resultant force of the dead weight of the body acting at its centre of gravity, together with the forces of the muscles and tensions of the ligaments, which, acting vertically through a point of the body which is placed vertically over the base of support of the body, balances the upward pressure of the base of support.

To be exact, the weight of the body acts in a line which falls just in front of the base of support/

support. The head, moreover, is not exactly balanced upon the trunk, but its own weight, acting at its centre of gravity again falls forwards of the line of support of the body, i.e. a little in front of the balancing point on the spine. These muscles have a power of contraction and relaxation within certain limits, by which the body can be inclined backwards or forwards more or less.

The head is mounted on the summit of the vertebral column, forming, as it were, its capital, in a manner obviously adapted for the vertical position.

Its centre of Gravity is a little in front of the summit to the spinal column, and therefore it would have a tendency to incline forwards, but this, as before, is resisted by muscles of adequate power, placed on the back of the neck. A healthy baby will hold up his head at 3 or 4 months, before this he merely waggles the head about, as if trying to balance it on his neck. The infant sits up at from 9 to 12 months, and will walk at from 12 to 18 months.(1)

Nothing/

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(1). Lectures on Diseases of Children.
Robt.Hutchison, London 1904.

Nothing more manifestly indicates the intention of nature that man should stand erect, than the position of his face, and the direction of his optic axes.

In the erect position, his face looks forwards and the optic axes are horizontal. But, if he were to assume the prone position, supported by his four members, like a quadruped, the optic axes would be directed downwards, and except by a strained effort of the neck, he could not see before him.

To this may be added that the knee joint being so constructed that the leg can only be deflected backwards on the thigh, would render the legs utterly unfitted to be members of support and locomotion in the prone position, since in that case the point of support would be, not the feet, but the knees.

Now independently of the consideration that in this case the legs and feet would not only become useless, but would be an impediment to every act of locomotion, the shortness of the thigh would inconveniently limit the power of progression, the thin integuments covering the knee pan itself, a loose detached bone would be displaced, and the members totally disabled.

Everything in the mechanical structure of the body conspires to prove that man was made to stand/

stand erect, and with this erect attitude are associated numerous consequences connected with his superiority over other species.

In man alone are found at once members which are exclusively prehensile, and others exclusively locomotive.

Man alone presents the characters of a really bimanous and bipedous animal.

In Man, the lower limbs are the principal organs of progression, and of maintaining the erect attitude. They are equal in length to the head and trunk together, while the upper extremities are comparatively short. The gluteal muscles are the largest in the body, and the calf muscles are of great power and terminate in a strong cord, the Tendo Achillis, the most powerful tendon in the body. This tendon narrows as it descends, but near the heel again expands slightly. It is inserted into the middle portion of the posterior surface of the os calcis (Cunningham).

These muscles would not, however, be sufficient, without a surface or base, on which the trunk itself could rest. This surface is supplied by a broad pelvis. The femora are joined to this by long necks, and the pelvis, in the human being, is of/

of peculiar breadth, presenting an upper and a lower arch, which meet at the hip joints, and is so inclined, that a vertical line descending from the Centre of Gravity of the body, is in a plane slightly behind the centres of motion of the Hip Joints. The breadth of the pelvis enables the balance to be more easily maintained in lateral movements of the body, by compensating inclinations of different parts, to opposite sides of the base of support, and the long neck of the femur, gives an advantageous insertion to the muscles, by which the balance of the body is principally preserved.

The hip bone is mainly distinguished from the same bone in animals by the breadth of its iliac portion, which gives support to the abdominal viscera, and attachment to the greatly developed iliac and gluteal muscles. (1)

In the orang and in all monkeys, the lower extremities are comparatively short, while the upper or arms, are very long, so as to allow the knuckles to be applied to the ground, when the animal is nearly erect. This is, in fact, the mode of progression amongst these animals, and always adopted when necessity requires this position.

The/

(1). Quain. Osteology Vol.II. Part I.

The pelvis is comparatively narrow in monkeys, and the femora are joined to it by short necks, which form more acute angles with the spine than is the case in Man. Quain says:- "In man, the lower limbs are remarkable for their length and strength. The femur is greatly elongated, its length considerably exceeding that of the tibia - a condition which is requisite, not only to give a sufficient extent of stride, but also to enable the body to be balanced in different degrees and varieties of stooping. The foot of man alone among animals, has an arched instep, and it likewise presents a great breadth of sole; the great toe is distinguished by its full development, and especially from that of the apes, by its want of opposability, being constructed, not for grasping, but for supporting the weight of the body and giving spring to the step."

These facts render the erect attitude impossible for any time in monkeys, and always irksome. The weakness of the muscles further confirms this. "The glutaei are scarcely visible and the calves are very weak." (1).

The extensors of the knee are much stronger in the human subject than in other mammalia, as their/

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(1) Cuvier. "Les fesses étoient presque nulles ainsique les mollets."

their operation of extending the thigh forwards on the leg forms a very essential part in the human mode of progression.

The flexors of the knee are, on the contrary stronger in animals, and are inserted so much lower down, even in monkeys, that the cord which they form, keeps the knee habitually bent, and almost prevents the perfect extension of the leg on the thigh. The motion of the knee joint in the Black Orang was free backwards, but the animal does not seem capable of perfect extension of this joint, from the contraction of the posterior muscles of the limb.(1).

The most remarkable muscle about the top of the thigh in Simiams(Orangs) appears to be the Scansorius - a flat triangular muscle, arising from the whole anterior edge of the ileum, to within half an inch of the Acetabulum, and is inserted just below the fore part of the great trochanter, between the head of the Cruralis and Vastus externus, a little below the origin of the former. It is thin and fleshy through its whole extent, except where it is inserted by a very short flattened tendon. At its upper/

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(1) Dr.Traill. Account of Black Orang. Wern.Soc.Trans. Vol.III p.29 quoted by Sir William Jardine. The Nat.History of Monkeys. Edinburgh 1833.

upper part it is united by cellular substance to the iliacus internus. The action of this muscle appears to be intended to assist in climbing. (1)

In man the foot is placed squarely on the ground resting on the balls of the great and little toes and the os calcis., the latter forms a right angle with the leg.

In the orangs, this bone begins to form an acute angle with this limb, and consequently does not rest upon the ground. The sole of the foot becomes narrower, and therefore, in all attempts at erect progression, exhibited by the orangs, which have been shown in this country, the foot was observed to rest upon its outer edge. The plantaris muscle also, which is fleshy among quadrumanous animals, instead of terminating, as it does in man, by insertion in the os calcis, passes over that bone, into the sole, and is there connected with the plantar aponeurosis - an arrangement incompatible with the erect attitude, as the tendon would be compressed, and its action impeded, if the heel rested on the ground. (Lawrence. Nat.History of Man.)

The upper extremity approaches much nearer to the human form, and in its similarity, points out the unfitness of these animals for a constant quadrupedal motion. The inferior structure of the hands/

(1) Traill.

hands, and particularly the thumbs, show them fitted for grasping alone, and incapable of performing any nice mechanical operation, while the great comparative length indicates their utility in climbing, and therefore, their fitness for an arboreal life.

The top of the head is flatter, and its union with the spine further back than in the Adult human being. The orbital processes of the frontal bone project beyond the general convexity of that bone, and the orbits of the eyes are proportionately larger and rounder than in man.

In the human being, the smaller development of the face as a whole, and especially of the jaws, which brings the facial bones almost entirely under the fore part of the brain case, tends to throw the weight of the head further back than in the anthropoid apes.

Again, the adaptation of the human skeleton to the erect posture, as regards the head, is attended with a sudden bend of the basicranial axis at a considerable angle upon the line of the erect vertebral column; and along with this, the great development of the cranium in a backward direction, whereby the occipita-vertebral articulation comes to be placed approximately in the centre of the antero-posterior/

posterior length of the skull, so that the head is nearly balanced on the upper extremity of the spine. (1). In most animals, the great occipital foramen, and the articular condyles are placed almost at the end of the skull, throwing the weight of the head forwards, and it is incapable of being supported by the vertebral column, without some very powerful assisting mechanism.

Hence, we find the spinous processes of the cervical vertebrae long, and assisted by a very strong ligament, the ligamentum nuchae, or suspensorium colli.

In the orang, the occipital foramen is placed twice as far from the jaws as from the back of the head, which throws a great additional weight forwards, and consequently requires more exertion to maintain the erect position.

But, although we find, according to Camper, that the spinous processes of the cervical vertebrae are long, there is no mention in any author of the presence of the suspensory ligament, which can be used as an argument that the natural gait of the orang is not that of a quadruped.

Another/

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(1) Quain. Vol.II., Part I., Osteology.

Another confirmation of this argument is the absence of the suspensorium oculi, a muscle found in quadrupeds, and evidently intended to relieve the others, and be a greater support to the eyes when continued in the prone condition.

These are the principal peculiarities of structure connected with progression and attitude in orangs, and it seems from these remarks that neither the erect nor the quadruped posture is the common and natural one in orangs (monkeys) and that they will employ either, as occasion requires.

From all these considerations, it follows that the shape of the Thorax will be different in the Adult Man from the Monkey and the Foetus, since these three are habitually placed in different attitudes, and the Thorax shares in the differences of shape produced in the various parts, due to the particular attitude adopted.

Moreover, we might infer that the shape of the monkey thorax would be intermediate between that of the foetus and the Adult Man.

We shall see later that in their chief relationships of shape, the full time foetus and the monkey in regard to the Thorax, present nearer relationships to each other than do either of them to that of Adult Man.

In fact, that if we take the shape of the Thorax/

Thorax of the Adult Man as the standard, then we shall find that the Monkey's Thorax is very far removed from this, and that the full time foetus is a little further removed from this, in the same direction, and that the younger the foetus, the further is it removed from standard.

Put in another way, we may say that we descend in shape from Man, through Monkey, then on through full time foetus, and so on in the same direction, until we arrive at the very earliest shape of chest formation, and that the greatest gap is between Man and Monkey. We shall proceed to see this more clearly by considering the different parts that conduce to the formation of the Thorax, in detail.

THE RIBS.

The curvatures of the ribs, in the horizontal plane, will first be considered. Each of the ribs is curved. A rib has been described in a general manner, to form arcs of two circles of unequal radii. (Humphry) This definition of the curvature misses the whole point of the argument. As a matter of fact, I find that there are more than two changes of curvature in all the ribs, except the twelfth, in the human adult. In the foetus and the monkey there are more than two changes except the eleventh, the twelfth ribs in the foetus and the monkey measured, being rudimentary. If a rib consisted of the arcs of two circles united together at the angle, then there could be no flattening sideways of the Thorax, a very noticeable feature of the foetus and the monkey, and in some extent also in the adult human female. The erect attitude assumed by the adult man, would, of itself, suggest a priori a twisting of the ribs, which again, in itself, would suggest an increase in the curvature of the ribs.

That this increase of the number of curvatures is the case, we shall see later on, these changes/

changes in curvature give an increased elasticity to the bones, and therefore, a means of greater resistance to injuries. This again enables them to offer a better protection to the underlying viscera. From the adoption of the erect posture by the adult man, the viscera that lie immediately under the front and sides of the chest wall, are obviously exposed to a variety of injuries to which the viscera of the quadrumanous animals are not subjected.

This suggests that there would be a greater number and variety of changes of curvature as we go upwards in the scale of posture from that of a quadrumanous animal to that of the Adult Man. The habitual attitude of the Monkey being between that of the quadrumanous animal, and that of the Adult Man, we might expect to find that the changes in curvature of the ribs of the monkey, should be intermediate between those of the foetus and of the adult man respectively, because the foetus in regard to vulnerability of the viscera that lie below the front and sides of its thoracic walls, may be put on the same level with the quadrumanous animal. We shall see afterwards, that, in regard to these changes of curvature, the Monkey actually does occupy the position, which is intermediate between that of a foetus, and that of an Adult Man. The first noticeable change/

change of curvature occurs near the hinder part - the angle - there is a rough ridge placed obliquely, running downwards and forwards across the outer part of the shaft at this point. From the head to the angle, the rib in its first course arches backwards. From the angle, with a changed curvature it proceeds onwards and forwards. The posterior projection caused by this arching backwards of the ribs, brings them nearly to a level with the spinous processes.

Various methods of measuring the curvatures of the ribs occurred to me, and all of these methods were tried. These methods will now be described in detail, and the results that can be obtained from them, pointed out.

METHOD OF MEASURING THE CURVATURE OF THE RIBS.

1st METHOD.

The disarticulated ribs were severally placed on a horizontal plane and tracings were taken of the inside of the rib.

The curvatures of the curve thus obtained were then measured by drawing the circles whose curve/

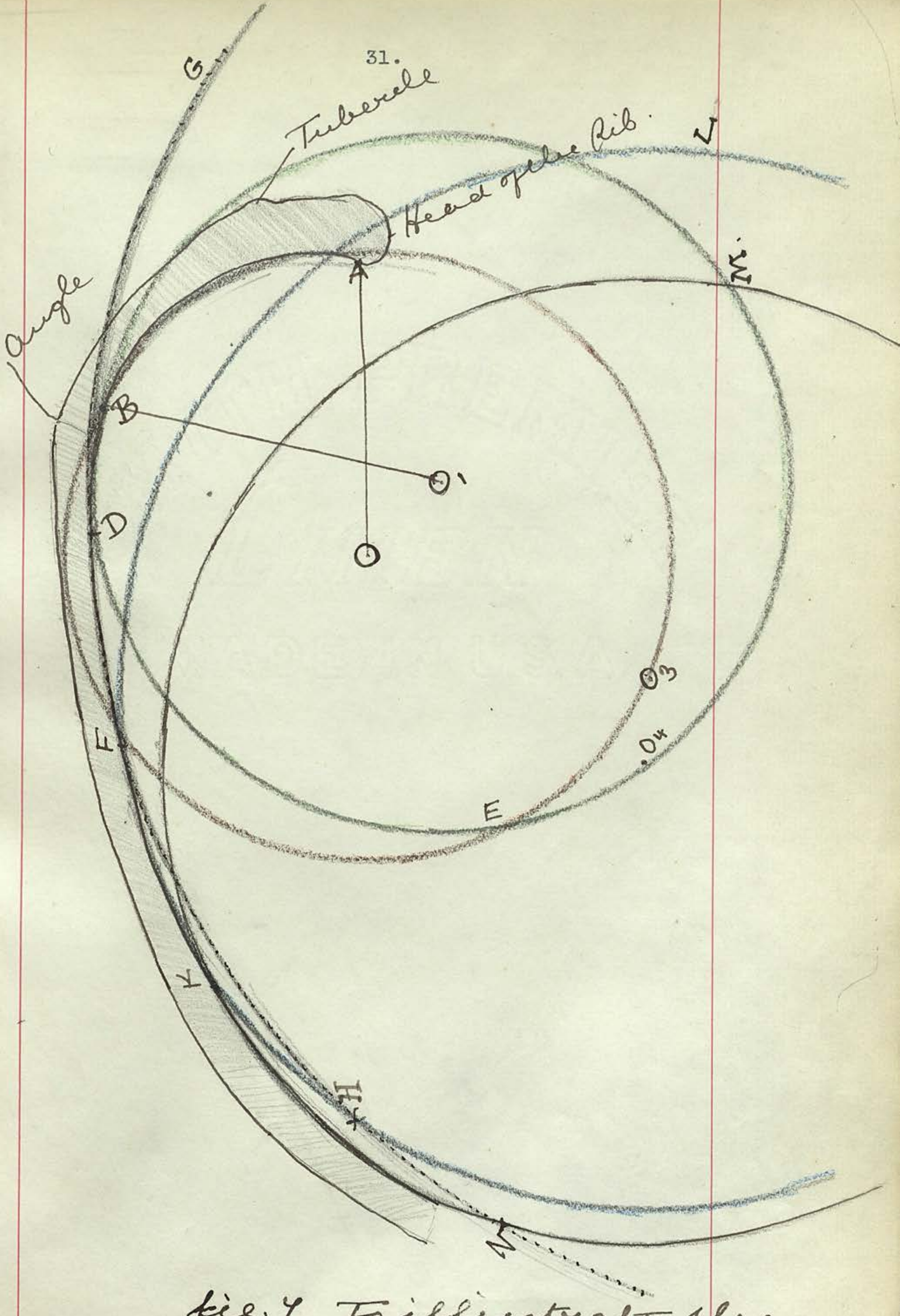

fig. 7 To illustrate the first method of measuring

curve corresponded most nearly with the portion of rib under consideration.

In the annexed Figure 7., the 6th rib has been dealt with in this way. It shows that this particular rib may be considered to be made up of segments of 5 different circles. The first whose centre is O. and whose circumference is ABE, coincides with the part of the rib AB from the head A to a point B opposite the angle, on the inner surface of the rib, and has a radius of 6.2 cm.

The second circle (centre O_1) and circumference B D E, coincides with the inner surface of the rib, from a point opposite the angle B. to the point D. The radius of this circle is 6.8.cm.

The third circle coincides with the circumference of the inner surface of the rib from D. to F. Its circumference is GDFHZ. Its radius is 17.2 cm.

The fourth circle coincides with the rib from F to K, circumference CFKH in the figure Centre O_3 and radius 10.6 cm.

The fifth and last of the series coincides with the rib from K to the bony end of the rib, circumference MKZ centre O_4 and radius 9.8 cm.

I/

I have found in every case that I have measured, a rib's curvature can be expressed in this way.

From a great number of measurements in this way, I always find that 4, or at most 5 circles can be found, whose radii fairly accurately express the curvatures of the rib at the different parts of its length.

The difficulties of this method are first, the accurate tracing of the outline of the rib. Furthermore, it must be determined whether the line of the upper border or the lower border or the locus of line of a point midway between the two borders, is to be traced out. Otherwise, we should be expressing, at one part of the curve, the locus of, say, the upper border, whilst a little further on, we might be tracing the locus of the lower border.

Again, it is necessary for the purpose of a calculation of this sort, to have the skeleton disarticulated. This is a great difficulty, as it is not easy to obtain many complete sets of disarticulated ribs. Moreover, there is a danger of getting odd ribs in a particular set, that do not really belong to that set.

Again/

Again, another objection to this method is, that, whilst the measurements of the radii of the circles is strictly mathematically correct, the drawing of the original curves from the rib itself can never be strictly mathematically correct, because of the small projections of bone that are continually met with, on the surface of the rib.

It serves very well, however, to illustrate the fact that the curve of a rib in the horizontal plane, can be considered to be made up accurately of the segments of four, or at most five circles of different radii.

2nd METHOD.

The Second Method which I used, and the one which gave the uniformly best results, was the following:-

Segments of circles were cut out of cardboard of different radii. These were fitted to the inner surfaces of the various ribs. I found the general results obtained corresponded well with those of the First Method, but with this advantage, that the results of one measurement of a given set of ribs agreed with another independent measurement very closely; whereas, in the First Method, so much depended on the curve obtained by tracing the rib, and then afterwards/

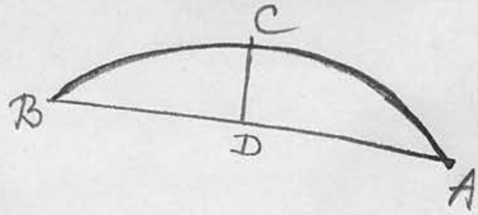

fig. 8.

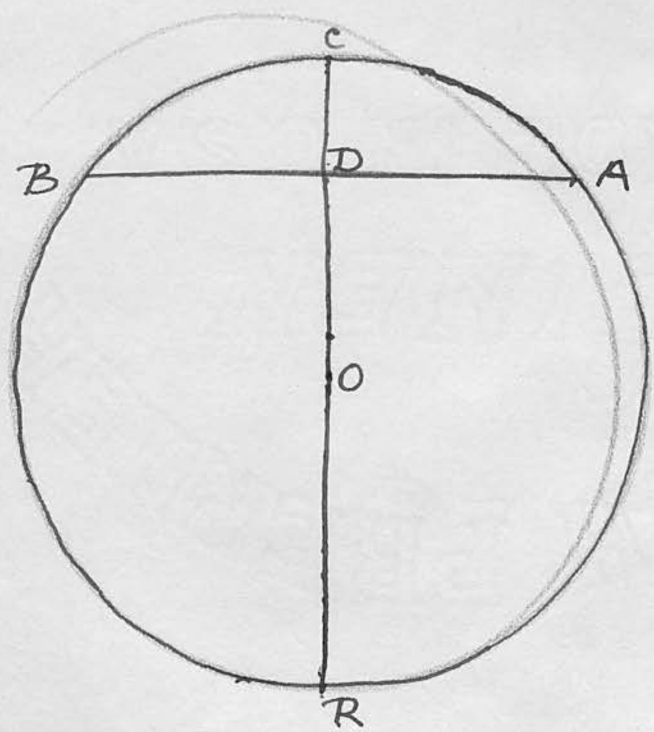

fig. 9.

afterwards drawing circles to fit the rib.

Moreover, this method was found to be very applicable to articulated specimens (e.g. Museum preparations) and also to thoraces (especially of the foetuses and orang) which had been hardened in formalin, and in which it was necessary to keep the parts together, as in life, in order to get the exact shape of the Thorax in life.

<u>3rd METHOD</u>. In this method, for example Fig.8, in measuring the radius of curvature of a rib in its first part, i.e. from the vertebral end to the angle, - A to B in the Figure 8, the cord A B was measured. Then the middle point(C) of the arc ACB was taken and a perpendicular CD dropped on the cord AB. This perpendicular was carefully measured. We are now in a position to estimate the radius of the circle of which ACB forms a segment.

Thus:- If as in Figure 9 -

The circle ACBR be completed,
of which ACB is a segment,

then producing the perpendicular CD to meet the circumference again in R, we know that the

Line CD bisects AB

since C is the middle point of the arc ACB,
and CD is drawn at right angles to AB.

Again, since CD bisects the cord AB of the circle at right angles, it must pass through the centre/

centre of the circle - say O.

And ∴ the line CDR is a diameter of the circle and ∴ equal to twice the radius.

Let the radius of the circle $= r$

& if the length of AB $= 2L$

& " " " " CD $= p$

we know that since the two cords CDR and AB of a circle intersect each other at the point D. that the rect. CD.DR = rect.BD.DA

Now $CD = p$

$DR = CR - CD = 2r - p$

& $BD = DA = L.$

$\therefore\ p(2r - p) = L^2$

or $2pr - p^2 = L^2$

or $2pr = L^2 + p^2$

or $r = \dfrac{L^2 + p^2}{2p}$ / (I)

We thus see that by accurately measuring the length of CD ($= p$) and AB = (2L) we can at once get the radius of the circle of which ACB forms part, or, in other words, determine the radius of curvature of the rib, in its course from the vertebral column A to the angle at B.

This method can be applied along the whole course of the rib, and by this means the various changes/

changes in curvature as we go, from one end of the rib to the other, can be demonstrated.

4th METHOD.

In this method, models of the various chests were made in plaster of Paris, and measurements were then taken of the models. Examples of these models are submitted with the Thesis. A series of measurements made in the manner indicated, are now added. The measurements were made on typical Thoraces.

In the first column are given the radii of curvature of the part of the rib from its head to its angle. In the 2nd column are given the radii of curvature of the 2nd portion of the rib, - that is from the angle forwards, and a distance forwards on the rib, equal to the distance from the head of the rib to its angle.

The other measurements are those of the last portion of the rib; this last portion being divided according to the changes of curvature that were found to take place. As we shall afterwards see in the Adult Male, there were as many as four changes of curvature in this portion, in some of the ribs. Whereas, in the orang, we never get more than three, and in the foetus only one change of curvature. It will thus be seen, that the first two measurements apply/

apply to that portion of the rib, in the region of the angle, whilst the rest apply to the greater portions of the ribs, i.e. the part which constitutes the lateral and anterior portions of the rib.

CURVATURES of RIBS MEASURED in CENTIMETRES.

In a Male Adult. (Sikh Museum Specimen).

	HEAD to ANGLE.	ANGLE ONWARDS to end of BONY RIB.			
	(1)	(2)[x]	(3)	(4)	(5)
1st RIB.	3	3.5	12		
2nd "	4	4.6	6.1	7	
3rd "	4.6	5	8	10	
4th "	4.9	5.3	10.5	13	14
5th "	5.3	6.1	12.5	14	
6th "	5.4	6.5	13	15	16
7th "	5.5	6.9	10	12	18
8th "	5.7	10	18		
9th "	6.1	10.5	16	18	
10th "	6.5	9	12	14	
11th "	5.7	7	9		
12th "	6.9	8			

In this case the greatest number of changes of curvature took place in the 7th Rib, and the greatest curvatures (18cm.) were found in the 7th, 8th, and 9th Ribs. The curvature in the first rib showed /

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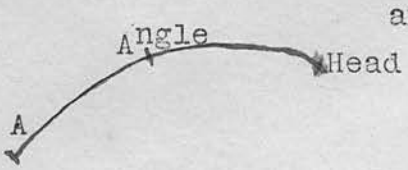
[x] Numbers under the Column (2) give the curvatures of the ribs for a distance on the other side of the angle removed from the head, equal to the distance from the head to the angle, or in the figure refers to curvatures from angle to A.



showed that on either side of the angle the curvature was much the same, but the last part of the rib - from the Scalene Tubercle to the end of the bony rib, the curvature was greatly increased. In fact, compared to that from the head to the angle and just beyond the angle, it was practically straight.

CURVATURES IN AN ADULT FEMALE, IN CENTIMETRES.

	HEAD to ANGLE.		ANGLE ONWARDS.		
	(1)	(2)	(3)	(4)	(5)
1st RIB.	2.3	2.5			
2nd "	3	3.4	5.7	8	
3rd "	3.4	4	6.9	11	
4th "	3.9	4.2	6.9	11	
5th "	4.2	5.3	6.9	12	
6th "	4.3	6.5	8	13	
7th "	4.6	6.9	9	14	
8th "	4.2	7	9	16	
9th "	4.9	8	14	15	
10th "	5.7	8	12	14	
11th "	5.3	6.5	11.5		
12th "	7	11			

It is to be remarked here, that the greatest curvature (16 cm.) occurs in the 8th Rib, and that it does not reach to nearly the same dimensions as in the Adult Man (18 cm.)

Moreover, the curvatures all over are less than in the adult man. Also there are not nearly so many changes of curvature.

This/

This female Thorax whose measurements are given above, does not give us much information from which we can draw many rigid facts, for it was very much distorted especially in the region of the lower ribs, probably from the constricting influence of corsets, as is frequently the case in the female Thorax. This distortion, however, has its least effect on the arc of the rib from the head to the angle, and we see from the curvatures given under the column headed "Head to Angle", that the ribs are constructed on a lesser scale than in the Male Adult. In the case of the 12th Ribs, the first curvature is seen to be greater than the corresponding measurement given in the Male, but this may be due to a small part of the front portion of the rib being included in the measurement of the curvature of the first portion, from the head to the angle, as the angle is practically not marked at all in the 12th Ribs, and also the above mentioned constricting influence of corsets would have an effect here also. The ribs are also flatter at the sides, so as to render the transverse diameter of the chest less in proportion to the antero-posterior.(1)

This flattening is seen by taking the first/

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(1) Humphry.

first two columns in each set of measurements under the heading "Angle Onwards" of comparing them.

Thus, taking the 3rd Ribs, in the Male, the first two curvatures from the angle onwards i.e. the curvatures of the sides of the rib are 5 cm. and 8 c.m., whereas in the female we have 4 cm. and 6.9 cm.

Now remembering that these are the measurements of similar portions of the ribs as they proceed from their angles onwards, and that the measures 4 cm. in the female and 5 cm. in the male, are the curvatures just where the ribs are beginning to bulge transversely, and that the measures 6.9 cm. and 8 cm. are the radii of curvature of the ribs in their middle portions, we see that in order to keep up the similarity of the curve in the two ribs, as we pass from 5 cm. of curvature to 8 cm. in the Male, we ought to pass from 4 cm. to -

$\frac{8 \times 4}{5}$ cm. i.e. 6.4 cm. in the Female for circles are to one another as their radii.

As a matter of fact, we pass from 4 to 6.9 cm. and thus as shown in the Fig.10, there is a flattening produced.

In the Figure AB and ab are the arcs of the Ribs from their angles onwards to their first changes/

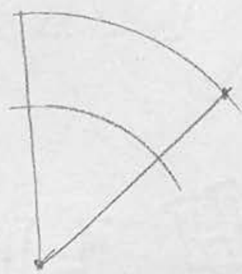

Diagram to shew the flattening produced in the female rib by the change of curvature.

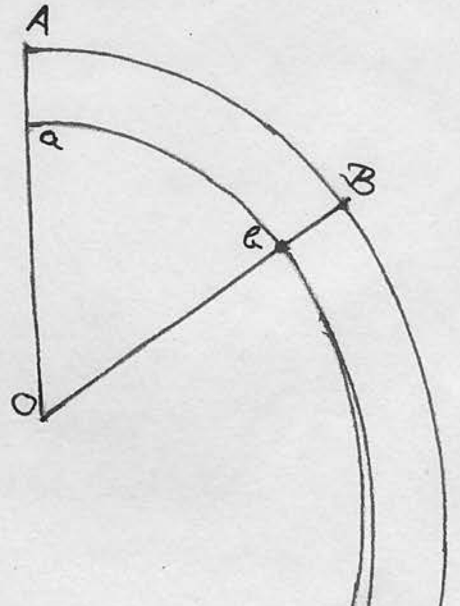

fig. 10

A & a are the angles of the two ribs respectively (male & female) changes of curvature at B & b respectively. Now, if the Male and Female Ribs preserved their similarity of form, we should have BC an arc of radius 8 cm. with O as centre for the next arc of the Male Rib and bc, for the next arc of the Female Rib, and thus the arcs BC and bc, would still be similar to one another, their radii being 8 cm. and 6.4 cm. respectively.

But actually the next portion of the Female Rib is represented by the arc bc.

The whole arc abc,, has thus been flattened at b into the position abc.

In the succeeding ribs this flattening is shown better.

It must be borne in mind, however, that this flattening which has been shown to take place as a result of the change in curvature at B and b, can only help to prove that the Transverse diameter is proportionally less and compared to Antero-posterior diameter in the Female, than in the Male, when we take this in conjunction with the absolute measurements of the radii of the arcs of the Male and Female Thoraces, at these similar parts of the same ribs, and also that these arguments only apply to the ribs for the parts of their course from their angles to about the middle of their shafts.

This may be put in a more correct way perhaps /

perhaps thus:-

The Transverse Diameter of the Thorax is less in comparison with the antero-posterior in the Female than in the Male Human Being. At the same time, but not necessarily having any connection with this fact, the third change of curvature in the rib in its course from its head towards its bony anterior extremity, or the second change from the angle towards its bony anterior extremity, is of such a nature as to cause a flattening of the rib at this place, as compared with the shape of the adult Male rib at the corresponding place on the corresponding rib.

I have put the limitation about the argument only applying to the ribs in a small part of their course, as obviously from the Fig.10, it will be seen, that if the Female Rib proceeded any length more than a small part of its course near the middle, with the curvature bc instead of bc_1, then the effect produced would be to widen the Transverse diameter proportionally to the antero-posterior.

The only exceptions to this in the table given occurs in the 2nd, 10th and 11th Ribs, and as pointed out above, the results in the last Ribs in the Female are vitiated by the external pressure that is usually applied. It is interesting to note here, that Meckel says, that the first two Ribs in the Female/

Female are absolutely a little larger than in the Male.

In the Orang the curvatures in centimetres of the ribs gave the following results.

RIBS.	HEAD to ANGLE. (1.	ANGLE ONWARDS to END of BONY RIB. (2)	(3)	(4)
1st.	9	1.8		
2nd.	1.4	1.7	2	
3rd	1.6	2.6	4	6.1
4th	1.7	3.2	4.2	7
5th	1.8	3.6	4.9	8
6th	1.85	4.2	5.3	9
7th	1.9	4.7	6.1	7
8th	2	5.2	6.3	
9th	2.2	5.3	6.5	
10th	2.4	5.9	6.5	
11th	3.1	6		
12th				

The 12th Rib was rudimentary as it was in all the foetuses examined.

There are not nearly the same number of changes of curvature here as in the Adult Male or Female.

The greatest curvature occurs in the 5th, and 6th Ribs. The curvature of the first part of the Rib increases from the 1st to the 11th Rib.

In the full time foetus, the curvatures of/

of the Ribs, again measured in centimetres, gave the following results:-

	HEAD to ANGLE.		ANGLE ONWARDS.	
RIB.	(1)	(2)	(3)	(4)
1st	5	7		
2nd	1.2	1.4	5.7	
3rd	1.3	1.6	6.5	
4th	1.4	1.9	7	
5th	1.5	2.2	7.5	
6th	1.5	2.4	8	
7th	1.7	2.4	6.7	
8th	1.8	2.6	5.3	
9th	1.9	3.1	4	
10th	1.95	2.2	3.1	
11th	2	2.2		
12th				

The 12th Ribs, as in the Monkey, were rudimentary. The curvature from the head to the angle shows an increase, as in the case of all, from first to the eleventh. A very noticeable feature, both in this series and in that relating to the Orang, is the small change of curvature in the first two Ribs. This agrees with Owen's remark, that in the Orang the 1st Rib is less curved and describes a smaller portion of a circle than in Man; and also that (1) in the Orang the other ribs chiefly differ in their more gradual and equable curvature.

It is also interesting to notice here, that in regard to the Chimpanzee, which is admittedly further/

(1) Anatomy of Vertebrates.

further removed from Man than is the Orang, that Owen remarks that:-

"The 1st and 2nd pairs of ribs are shorter, and their necks relatively longer than in the Orang, and are more curved."

In all the series, it will be noticed that the differences in curvature of the different portions of a rib, are much less in the first and the lowest ribs.

This may be accounted for by the fact that these ribs have least concern in determining the shape of the Thorax. These ribs are the only ones of the series that at all approximate in their shape to the arc of one large circle.

THE CURVATURES in the 6 MONTHS' FOETUS GAVE THE FOLLOWING RESULTS:-

RIB	HEAD to ANGLE.		ANGLE ONWARDS.	
	(1)	(2)	(3)	(4)
1st	.5	.55		
2nd	1	1.2	6.1	
3rd	1.1	1.4	6.5	
4th	1.2	1.5	7	
5th	1.3	1.6		9
6th	1.5	1.8	4	8
7th	1.65	1.9	6.5	
8th	1.7	1.9	5.3	
9th	1.8	2.1	4.9	
10th	1.85	2	4	
11th	1.9	3.5		

Again/

Again we notice that the curvaturesincrease in the first part of the rib from the head to the angle, as we proceed from the 1st to the 11th . The still smaller change in curvature along the first rib, is very noticeable. In fact, the First Rib may very well be described in the 6th month foetus, as consisting of the arc of one circle, so small is the change of curvature along it.

From a consideration of these measurements we see that as a general rule, taking the ribs all through a given set, there are more changes of curvature observed in the adult human being than there are in the Orang and Foetus.

In the Adult Male with the exception of the shortest ribs, the 1st, 10th and 11th, there are at least four changes of curvature - in three instances there are as many as five. In the Orang, five of the Ribs show four changes of curvature, whilst in all the rest, with the exception of the first and last, three changes of curvature at most are to be noticed. Again, in the Foetus none of the ribs show more than three changes of curvature.

We may, therefore, conclude that the nearer erect posture we get, the more changes in curvature are we likely to obtain in the Ribs.

Again/

Again, taking the measurements of the curvatures of the last portions of the Rib, i.e. as given in the tables of measurement from the angle to the end of the Bony Rib, we have :-

RIB	IN ADULT MAN.				6 MONTHS' FOETUS.	
	(1)	(2)	(3)	(4)	(1)	(2)
2nd	4.6	6.1	7		1.2	6.1
3rd	5	8	10		1.4	6.5
4th	5.3	10.5	13	14	1.5	7
5th	6.1	12.5	14		1.6	9
6th	6.5	13	15	16	1.8	8
7th	6.9	10	12	18	1.9	6.5
8th	.10	18			1.9	5.3
9th	10.5	16	18		2.1	4.9
10th	9	12	14		2	4

	ORANG			FULL TIME FOETUS.	
2nd	1.7	2		1.4	5.7
3rd	2.6	4	6.1	1.6	6.5
4th	3.2	4.2	7	1.9	7
5th	3.6	4.9	8	2.2	7.5
6th	4.2	5.3	9	2.4	8
7th	4.7	6.1	7	2.4	6.7
8th	5.2	6.3		2.6	5.3
9th	5.3	6.5		3.1	4
10th	5.9	6.5		2.2	3.1

We see at once from the Tables, that the changes of curvature in the Adult Man are not nearly so abrupt in the latter part of a Rib, as they are in any of the others. Thus, taking the 5th Rib in the Adult Man, we have the curvature ranging from 6.1 cm. next the angle, on through 12.5 cm. and finishing up with 14 cm. Whereas, in the corresponding Rib in the/

the 6 Months' Foetus we have the curvature changing from 1.6 cm. to 9 cm.

Again, taking the Full Time Foetus, we have for the changes of curvature in the 5th Rib, the measurements 2.2 for the portion next the angle to 7.5 cm.

In the Orang, the curvature change is more abrupt than in the Adult Man, thus in the 5th Rib it goes from 3.6 cm. near the angle, to 8 cm. in the last portion of the Rib; but there is a considerable difference between the measures of the Orang and those of the Foetuses, the latter having the more abrupt changes.

Again, remembering that the last two columns of figures give the radii of curvature in centimetres of the portions of the ribs that constitute the side and front walls of the Thorax, we notice a flattening of the lateral portions of Ribs in the Orang and the Foetuses, compared with those of the Adult Male.

This may be explained and illustrated in this way. In Fig.11, a diagrammatic representation of the 5th Ribs is given, of the Adult Man, the Orang, and the Full Time and Six months. Foetuses. ABCD is the Adult Man's Rib, from the Angle A to the end of the/

the Bony Rib.

AB represents the portion of the rib, equal in length to the portion of rib from the head to the angle and has a radius of curvature of 6.1.cm.

BC is the portion of the rib whose radius of curvature is 12.5 cm., and -

CD is the front portion of rib whose radius of curvature is 14 cm.

abcd is the Orang's Rib.

ab from angle onwards radius of curvature = 3.6 cm.

bc with a radius of curvature = 4.9 cm.

cd " " " = 8 cm. and

$\alpha\beta\gamma$ is the rib of the Full Time Foetus with

$\alpha\beta$ having a radius of curvature of 1.6 cm.
and $\beta\gamma$ " " " 8.cm.

and $\alpha_1\beta_1\gamma_1$ is the rib of the Six Months' Foetus, with $\alpha_1\beta_1$ having a radius of curvature of 1.6 cm. and $\beta_1\gamma_1$ having a radius of curvature of 9 cm.

The flattening of the middle portion of each rib is made obvious in this way from the diagram, and we see that the flattening increases as we go down in the scale through Orang to the Six Months' Foetus.

It will be noticed from the Tables of measurement that the flattening is greatest in the middle portion of each set of Ribs, and, therefore, affects chiefly those Ribs that take most share in the/

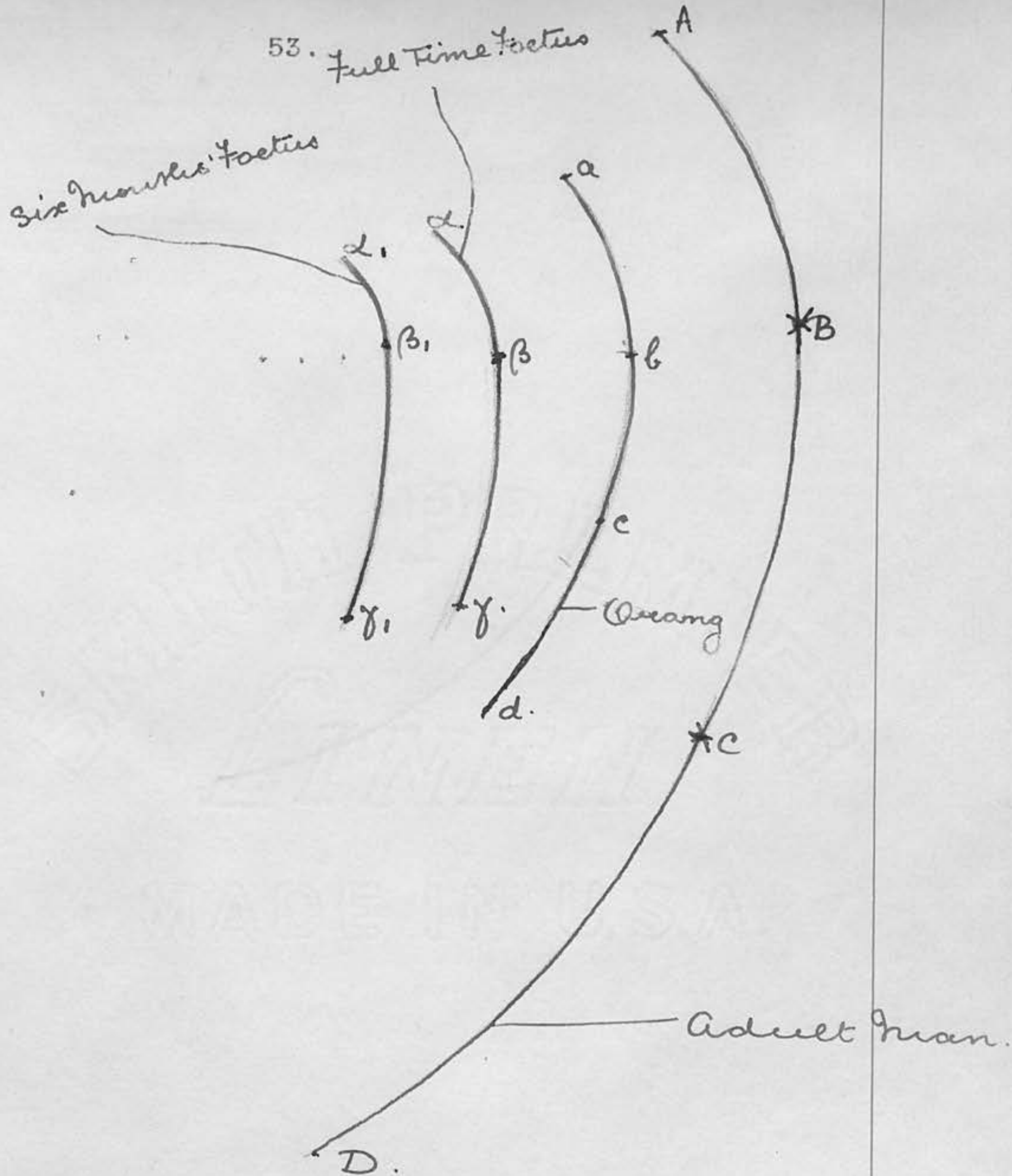

fig. 11. To illustrate the flattening of the ribs that takes place owing to change of curvature. in the 5th rib of adult man. Orang. Full time foetus & Six months' foetus.

the formation of the shape of the Thorax.

The great changes in curvature begin to be more marked in the earlier ribs in the Orang, than in the Adult Man; but still earlier marked in the Foetuses than in the Orang.

Thus in the Adult Man the changes begin to be well marked in the 4th rib, whose curvatures give 10.5, 13 and 14 cm. respectively.

In the Orang, the marked change begins in the 3rd Rib whose curvatures are 4 cm. and 6.1 cm respectively, whilst in the Foetuses, both full time and Six Months' the great change is observed first in the 2nd Ribs, whose curvatures are 1.4 cm. and 5.7 cm. and 1.2 cm. and 6.1 cm. respectively.

We may show the change of curvature in another way, thus:-

In the 6th month Foetus, it begins to be marked, first in the 2nd Rib and increases up to the 5th; in the Full Time Foetus and the Orang, the increase goes on to the 6th Ribs, in which we get the greatest difference of curvature between one portion of a rib and another, that is noticeable.

Whilst in the Adult Man, the greatest changes in curvature occur in the Ribs from the 4th to the 9th.

We see that the Monkey in this respect, again/

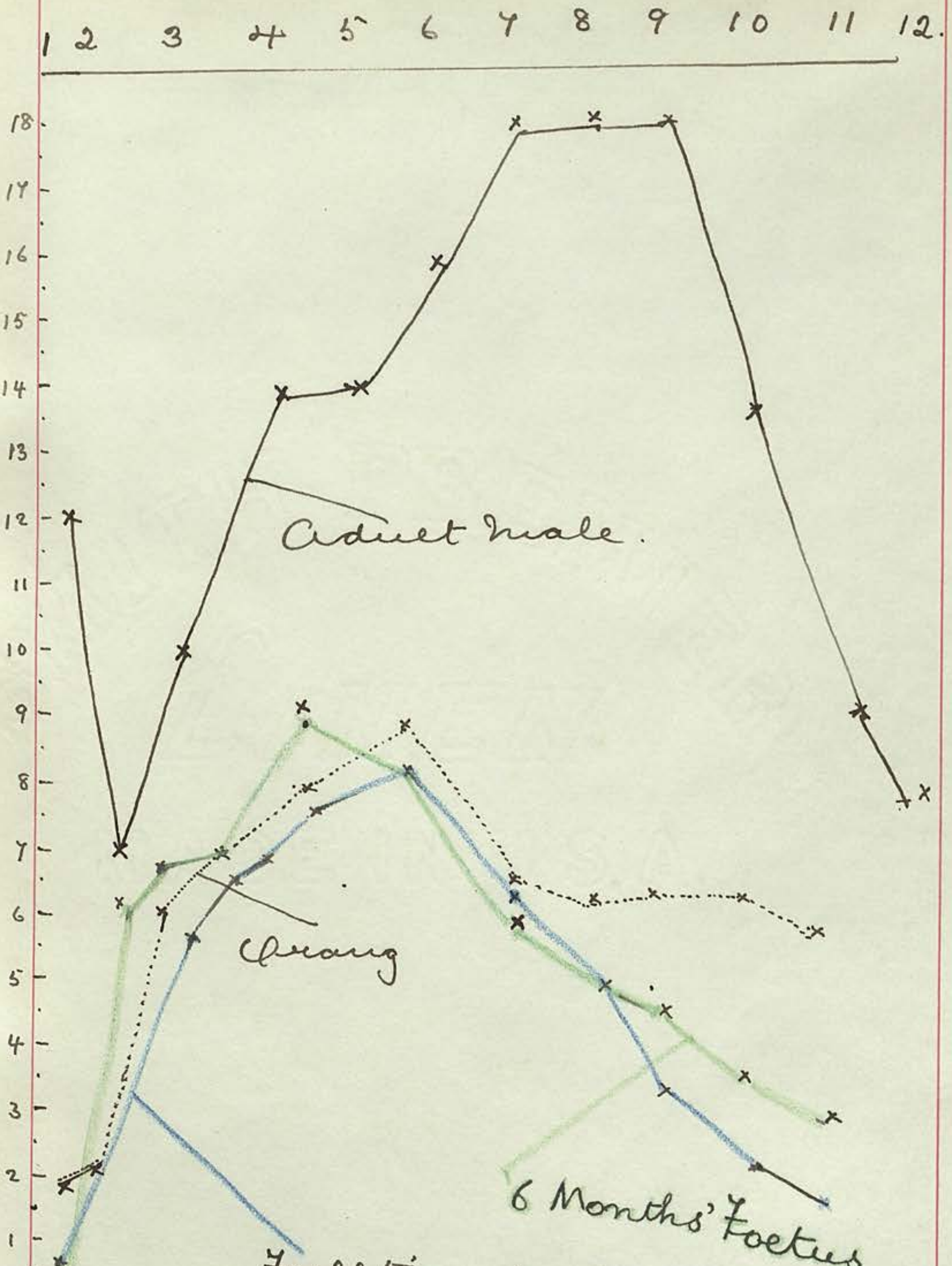

fig. 12. Diagram to show the maximum diameters in the piles of the adult Male. The Orang (dotted line), the full time foetus (in blue) & the six months' foetus (in green)

again occupies an intermediate position between the Adult Man on the one side, and the Foetuses on the other; and that the order of the series is - Adult Man, Monkey, Full Time Foetus, and Six months' Foetus. The maximum changes of curvature may be represented diagramatically as in the Figure 12. The diagram shows that the 6 months' Foetus attains its maximum curvature earlier than any of the others, and more abruptly than any of them. It rises to its maximum at the 5th Rib, and then falls to the 11th Rib. The fall, however, is considerably less abrupt than the rise.

The Full Time Foetus and the Orang, both attain their highest curvature at the 6th Rib. The rise in these two is more gradual than in the 6 months' Foetus, and in each of them follows a very similar course. They both then gradually fall down to the 11th Rib. The fall of the Foetus, is, however, more abruptly performed than that of the Orang.

In fact the Orang in its fall resembles more nearly the Six Months than the Full Time Foetus. The curve in the case of the Adult Man is seen to be different in every way from that in the case of the Monkey & the Foetuses. The highest point is not touched until we get to the 7th rib. It is then kept at/

at this point up to the ninth and then falls more abruptly to the end than is the case in any of the others.

It is quite obvious from the diagram that the curve of the Adult Man is quite removed in every way from that of the others and that the curve of the Monkey is intermediate between the two Foetuses.

Humphrey remarks (1) that "The bones are in very few, or in no instances found to be straight. The variety of curves & twists which they present gives a slight obliquity to all the movements, which has a great influence in imparting ease and grace to the carriage. Moreover, these curves & twists by imparting greater elasticity to the bones, have much influence in preventing the communication of jars from one part to the other, thus lessening the liability to fractures, dislocations and other injuries of the skeleton as well as to concussion and laceration of the soft parts. By the direction which they take they afford additional space and leverage to the muscles where these are most required."

We see from the above measurements that, as we should be led to expect, the longer the rib the more/

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(1) p. 12. Human Skeleton.

more numerous would be the changes of curvature, as in the above lists it will be noticed that most changes are exhibited by the 7th & 8th ribs. These are usually the longest ribs in the Adult, the Foetus and the Monkey. They are from 2½ to 3 times the length of the 1st & 12th ribs respectively. (1)

We also see that the change of curvature at the angle gradually increases from the first to the 8th rib and then gradually decreases. This follows the same law as the increase of distance between the Tubercle & the angle which is greatest on the 8th rib, & above that the width between these two points gradually decreases, until the two coincide in the first rib. (2)

Owen (3) remarks that in Orangs the 1st rib is less curved & describes a smaller portion of a circle than in man. The other ribs slightly differ in their more compressed form, and their more gradual & equable curvature.

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(1) Cunningham. Anatomy Osteology p. 99
(2) Cunningham ibid
(3) Anatomy of Vertebrates.

THE COMPARISON OF THE CURVATURES OF THE RIBS FROM THEIR HEADS TO THEIR ANGLES IN THE ADULT MAN THE ORANG & THE HUMAN FOETUS.

The Employment of a Mathematical Investigation.

It may seem at first sight to be impossible to employ exact Mathematical methods to the investigations of Anatomy, but on careful consideration this will be seen not to be the case.

The first objection to this mode will be that, e.g. in endeavouring to arrive at the curvature of a rib, there are too many irregularities, small projections etc. on the surface, to enable one to get the exact curvature. But it must be remembered that these irregularities themselves follow a definite law, e.g. the Scalene Tubercle on the 1st Rib. This Tubercle occurs on all first ribs, and therefore it is possible to estimate the relations of this bone, say, without considering this particular tubercle at all, since it occurs in all of them. Then, one can calculate the amount of difference that this makes, in correcting the results obtained, because, it is a constant factor, in all typical ribs, and ought to bear a fixed and definite relationship to the rest of the rib.

Again, all organs and parts of the body

in /

in their growth, exhibit a fixed and determinate relationship to each other: as also, for example, all bones grow according to some definite law. So that, on the completion of their growth, they have assumed a definite shape, and one common to them all. This being the case, it follows that it is possible to put into mathematical language the law of their growth and relationship to each other.

The late Professor Goodsir (1) on this question, remarks:- "That anatomy has hitherto advanced by the study of the animal form and of the exact harmony under which only the animal could exist. But there was another view which might be taken. Was it not possible by ascertaining the accurate shape, the form and proportion between the parts, organs, and whole body of any animal, to advance the study geometrically. Suppose the Anatomist gave the exact curvature of the surface the volume and proportions which different parts of the organs might bear - what their formal geometry was might become matter of calculation.

He might begin, by the lengths and breadths and/

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(1) Goodsir on the Employment of Mathematical Modes of investigation in the Determination of Organic forms.
Anat. Memoirs of John Goodsir. Edited by W. Turner. A. & C. Black, Edinr. 1868.

and volumes of the different parts: by ascertaining whether they have a correspondency, and exhibit a mathematical relation, spherical or spheriodal curves etc. These once ascertained he would become certain of the geometrical construction, and could reason as to the probable forms of other parts.

Impossible as it might appear, this has been effected in certain instances, and especially in a most beautiful manner in regard to shells of Molluscous animals, by the Rev. Professor Moseley, late of Cambridge (Philosoph. Transactions 1838, p. 351) who had made an exact geometrical examination of shells and especially of the Turbines, which were possessed of a spiral curve, wound round a central axis, which curve had been found to be logarithmic, and from it had been framed a series of formulae by which the other conditions of the shell could be predicted and found to exist.

The same idea, as expressed above in Goodsir's writings, is noticed in the following remarks of Humphrey (1) on Pressure influencing the shape of bones. He says "The shape of bones - and here it may be remarked that the uniformity with which they/

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(1) Humphrey. Human Skeleton p. 48

they acquire their proper shape is truly marvellous - must be due chiefly to those same developmental forces whereby the shape of the body generally is determined. Future investigation may point out the proximate causes by which shape is evolved; at present we have little or no clue to them. There are, however, some few secondary agents - assistants as they may be termed - to the primary developmental processes - whose influence we can trace in moulding the shape etc. of the bones: one of the chief of these is Pressure."

He then goes on to speak of the results of pressure of the parts enveloped by them on the cranial, thoracic, and other bones, whilst the osseous material is in its soft growing state. In these paragraphs he speaks of'Forces of Development' & 'Pressure' as the agents that cause the curvatures of bones.

Under 'Forces of Development' would fall all the molecular forces that are called into play between the infinite number of molecules of which the body is composed. By 'Pressure' he means the finite forces that are called into play e.g. by the viscera beneath the growing bones.

In any case these 'Pressures', 'Tensions' 'Forces of Development' etc can all be arranged under the term 'Force'.

We/

We arrive at this conclusion that all the changes in the body are the result of some 'Force'. Now Force can be measured by the effects it produces: if we can get a measure of the changes (e.g. in the curvature of bones etc. during the course of their development) we shall also be able to measure the force or forces that produced these changes.

In other words, by reasoning in this way we should be able by ascertaining the exact form or shape of a part to get back to the original 'Force' which produced this shape, and should then be able to start from this 'Force' once more, and reason correctly as to the exact shape or form which this known 'Force' would, indeed must produce in any other part.

Taking the curvatures of the bones there is no doubt that this is influenced by the pressure of the underlying viscera on them, by the action of muscles pulling on them in the foetal state, as well as by what Humphrey calls the 'Forces of Development which called them into existence'. This latter statement he says is proved by "their being modelled in the foetal cartilage and by their not unfrequently possessing an independent centre of ossification, as in the case of the trochanters of the femur and the tubercle of the radius".

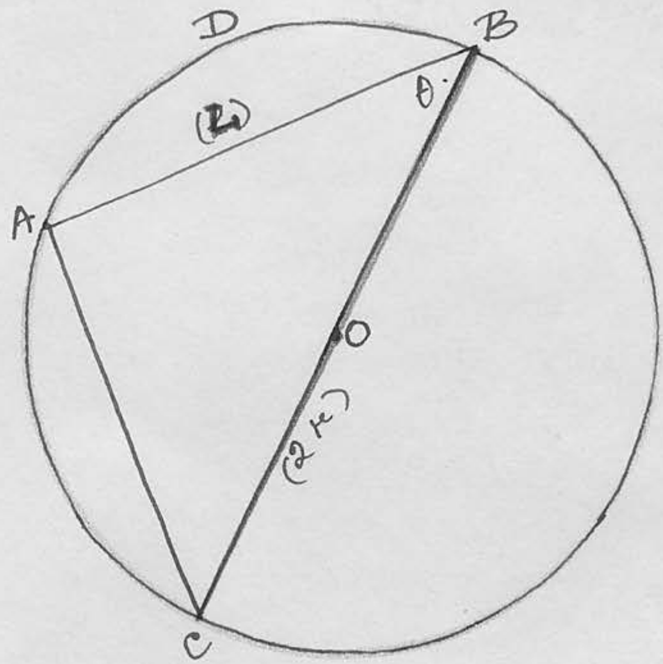

fig. 12.

To illustrate Prop. I. The angle at A (CAB), being in a semicircle is a right angle.
BC is the diameter of the circle & is therefore $= 2r$ where r is the radius of the circle.

It will be here necessary first to establish a few elementary propositions, in regard to arcs of circles and their chords.

P R O P O S I T I O N I.

Let ACBD be a circle & AB any chord
Join B to the centre O & produce it to meet the circumference again at C.
Then obviously BC = 2r where r is the radius of of the circle.
Let the angle ABC be denoted by θ
Join AC.

Now the angle CAB, being in a semicircle is a right angle. Let the length of AB be denoted by L.

We now see from the figure [12] that AB is the base of a right angled triangle ABC & BC is the hypotemese.

$\therefore$ the ratios of the angle θ can be expressed in terms of the sides of the triangle ABC.
Thus the cosine of the angle θ

i.e. $\text{Cos.}\ \theta = \frac{AB}{CD} = \frac{l}{2r}.$

By measuring the length L and finding the radius of the circle, we thus have at once a measure of the cosine of angle θ.

P R O P O S I T I O N II.

To show that the cosine of an angle decreases

in/

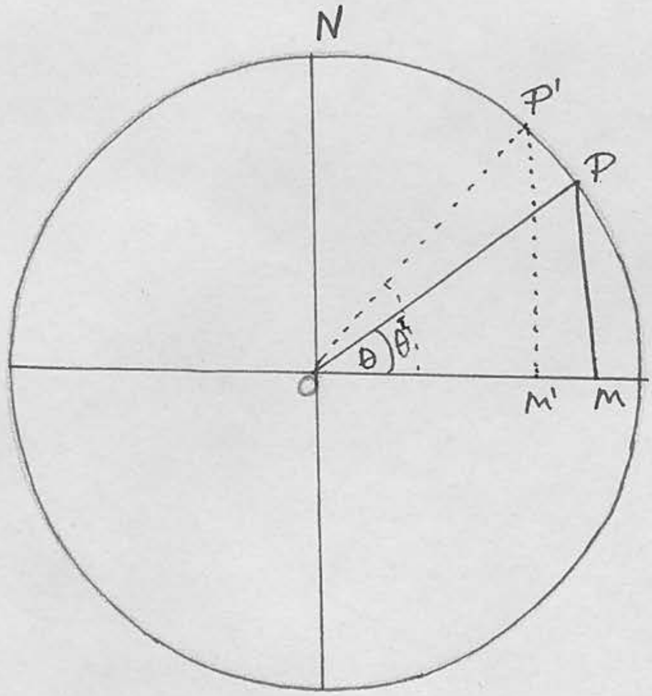

fig. 13.

To illustrate Prop. II.
The angle POM is denoted by θ, & the angle P'OM' by θ^{I}
OP & OP' are radii of the circle & are therefore equal.

in value from zero to unity as the angle increases.

From 0^{o} to 90^{o}.

In the triangle MOP let the angle POM be denoted by θ

Then the cosine = $\frac{OM}{OP}$.

Now as P moves round the circle towards N. up to the new position P^{1}, the angle POM increases from θ up to $P^{1}OM^{1}$ say θ^{1}

We now have Cos. $\theta^{1} = \frac{OM^{I}}{OP^{1}}$

Whereas Cos $\theta = \frac{OM}{OP}$.

Now Cos. θ^{1} is . . less than Cos. θ because the denominators OP & OP^{1} are equal, but the numerator OM^{1} is less than the numerator OM, which is at once seen on reference to the figure.

PROPOSITION III.

Going back to our original figure 14 we see that if we wish to increase the length (L) of the chord AB we must take it nearer to the centre e.g. $A^{1}B^{1}$. The angle ABC (θ) is now changed to $A^{1}B^{1}C^{1}$ (say θ^{1})

Cos. θ^{1} now = $\frac{A^{1}B^{1}}{2r}$ but since $A^{1}B^{1}$ is greater than AB, we see that Cos. θ^{1} is greater than Cos. θ, or in other words by Prop. II. the angle θ^{1} is less than the angle θ.

Again/

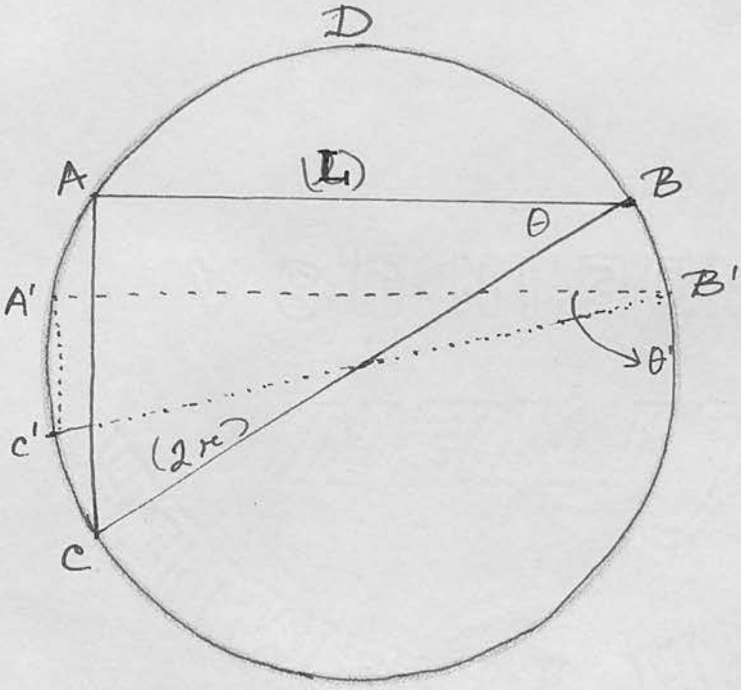

fig. 14.

To illustrate Prop. III. & Prop. IV

The cosine of the angle θ (ABC) is seen from the fig. to be = $\frac{AB}{BC}$ that is = $\frac{L}{2r}$ since BC = 2r being the diameter of the circle

Again by taking our chord nearer to the centre, we have increased the length of the arc BDA to $B^1D^1A^1$.

We thus come to the conclusion that when we increase the length of the arc BDA and the chord AB (L) we necessarily diminish the size of the angle ABC (or θ), or put in another way, as we increase the length of the arc BDA or the chord AB (L) we increase the size of the fraction $\frac{L}{2r}$ i.e. the cosine of the angle θ.

Keeping these propositions in front of us we now proceed to study the curves of the ribs from their heads to their angles, and see what, if any, are the differences of these curves in the Adult Man, the Foetus and the Anthropoid Apes (in this case represented by the Orang). We shall see that there is a regular series of changes as we go up in the scale from the youngest Foetus up to Adult Man.

P R O P O S I T I O N IV.

Now the size of this angle θ can be used as a measure of the size of the arc BDA. *fig. 14.*

For as we increase the arc BDA to $B^1D^1A^1$ the angle in the segment BDA is greater than the angle in the/

the greater segment $B^1 D A^1$.

Now, of course as we increase the size of our arc BDA so do we diminish the size of the remainder of the circumference of the circle BDAC.

Again the angle BCA which is = $90^o - \theta$, is increased as we change our first arc from BDA to $B^1 D A^1$ and vice versa, because by increasing our first arc, we diminish the remaining part of the circumference of the circle & ∴ by so doing we diminish the segment of the circle from BCA to $B^1 C A^1$ and by Euclid Bk. III. the angle in a segment of a given circle increases or diminishes according as the segment decreases or increases. We thus see that the angle θ can be used as a measure of the size of the angle $90^o - \theta$, and thus indirectly as a means of telling us whether we are increasing or diminishing the size of the arc BCA, and thus whether we are diminishing or increasing the size of our original arc BDA. Now, as we have shown, the cosine of the angle θ is measured by the ratio $\frac{L}{2r}$.

We can thus by measuring these two lengths L & 2r, tell at once whether the size of the angle & ∴ of the segment of the circle of which each of the ribs from their head to their angles increases or decreases. We can furthermore, by taking and comparing corresponding ribs, in say Adult Man & Monkey, and measuring/

measuring the lengths L & 2r i.e. the length of the chord of the rib from the head to the angle, and the diameter of the circle of which this part of the rib consists, tell whether the ratio $\frac{L}{2r}$ is greater or less in the case of Man than in Monkey.

We shall afterwards see that the ratio $\frac{L}{2r}$ is greatest in Man (Adult) and then goes on diminishing as we proceed down through the Series, Adult Man, Monkey, Full Time Foetus and Six Months' Foetus.

The ratio $\frac{L}{2r}$ increases if the angle θ decreases, being as we have pointed out the cosine of the angle θ.

Again, if the ratio $\frac{L}{2r}$ is greater say in the case of the 2nd or 3rd ribs of the Adult Man than it is in the case of the 2nd & 3rd ribs of the Monkey, we shall know that there are greater arcs of the circles of which these parts of the ribs consist (i.e. from their heads to their angles) in the case of the Adult Man than in the case of the Monkey.

We shall now proceed to give the measurements and work out and compare the ratios $\frac{L}{2r}$ in the case of all the ribs of all the dissections, and shall show that in all cases we can prove that in any pair of corresponding ribs, the ratio is greater in Man than in Monkey. That it is greater in Monkey than in full/

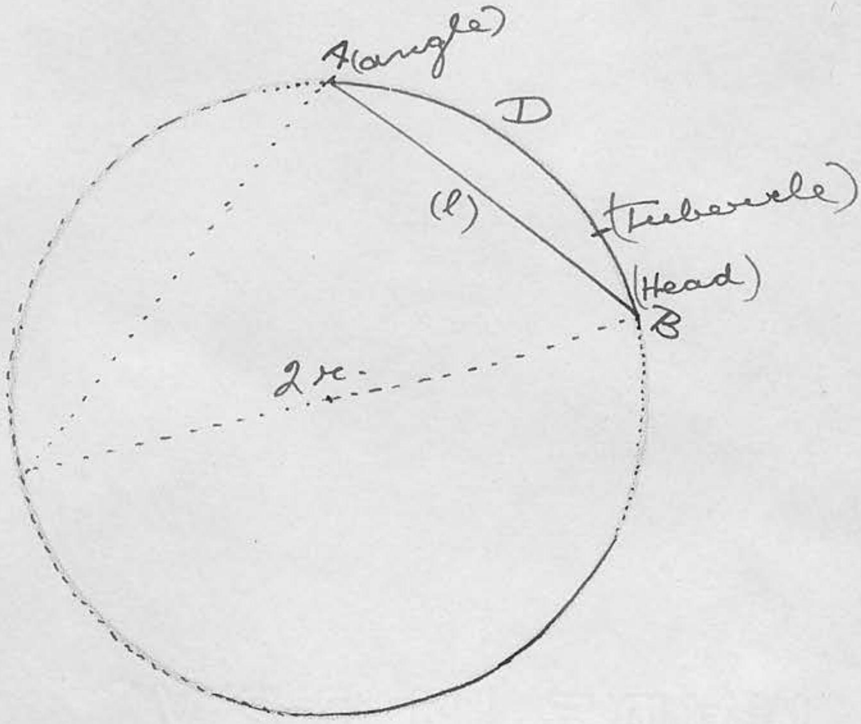

fig. 15.

The arc of the circle from B to A through D represents the rib from its head to its angle. The rest of the circle, of which the arc BDA forms a part is shown in the figure.

full time Foetus and greater in this latter case than in that of the Six Months' Foetus.

In the case of the ribs of a young child, which were measured I found that the ratio $\frac{L}{2r}$ lay in value between that of the Adult Man & the Monkey.

This indicates that the changes in the ribs, in the manner we are now discussing, goes on after birth until adult life is reached, as the ratio had increased from that of the child at birth, had passed the corresponding ratio in the Monkey, but fell short of what was obtained in Adult Man. I have worked out the ratio for each rib separately.

The length L from the head of the rib B to the angle (A) and the radius of the circle of which this part of the rib forms a segment, were carefully measured in the case of Adults, Foetuses and the Orang. Taking therefore, the average measurements (L) of the chord of the arc of the rib from its head to its angles and also the corresponding radius of curvature, we have in typical cases.

CURVATURES (r) MEASURED IN CENTIMETRES.

RIB.	ADULT MAN.	MONKEY.	FULL TIME FOETUS.	SIX MONTHS' FOETUS.
1st	2.5	.9	.5	.5
2nd	3.5	1.4	1.2	1
3rd	4	1.6	1.3	1.1
4th	4.4	1.7	1.4	1.2
5th	4.6	1.8	1.5	1.3
6th	4.75	1.85	1.5	1.5
7th	4.9	1.9	1.7	1.65
8th	5.3	2	1.8	1.7
9th	5.9	2.2	1.9	1.8
10th	6.1	2.4	1.95	1.85
11th	5.7	3.1	2	1.9
12th				

Similarly the lengths of the chords (L) are found to be:-

In

RIB.	ADULT MAN.	MONKEY.	FULL TIME FOETUS.	SIX MONTHS' FOETUS.
1st	2.8	9.5	.5	.4
2nd	4.15	1.3	1.1	.9
3rd	5	1.8	1.3	1
4th	5.7	2.1	1.45	1.2
5th	6.1	2.25	1.5	1.25
6th	6.3	2.4	1.65	1.3
7th	6.8	2.5	1.7	1.4
8th	7.1	2.6	1.8	1.5
9th	6.9	2.4	1.5	1.3
10th	6.7	2.2	1.3	.9
11th	5.7	1.65	.8	.6
12th				

We shall now take the ratios in each case of/

of Man & Monkey and compare them: then in the case of Monkey & Full Time Foetus: next in the case of Full Time Foetus & Six Months' Foetus, and show that it increases as we go down the scale.

Taking the ratio $\frac{L}{2r}$ in the case of each rib, in the Adult Man and the Monkey we find, on comparing this ratio:-

<u>In the first Rib,</u>

MAN.	MONKEY.
$\frac{2.8}{5}$	$\frac{.95}{1.8}$
i.e. $\frac{14}{25}$	$\frac{19}{36}$

which?

Bringing these ratios to a common denominator we get-

504 compared to 475.

We thus see that the ratio $\frac{L}{2r}$ or Cos. θ is greater in the Adult Man than in the Monkey. This shows that the arc of the circle of which the rib forms part increases at a greater ratio in the Man than in the Monkey.

<u>In the 2nd Rib.</u>

MAN.	MONKEY.
$\frac{4.15}{7}$	$\frac{1.3}{2.8}$
i.e. $\frac{83}{35}$	$\frac{13}{7}$

581 compared to 455.

Thus again the ratio is greater in Man

being/

being as 581 to 455.

3rd Rib.

MAN.	MONKEY.
$\frac{5}{8}$	$\frac{9}{16}$

80 to 72

4th Rib.

MAN.	MONKEY.
$\frac{5.7}{8.8}$	$\frac{2.1}{3.4}$
$\frac{19}{44}$	$\frac{7}{17}$

323 to 308

5th Rib.

MAN.	MONKEY.
$\frac{6.1}{9.2}$	$\frac{5}{8}$

488 to 460

6th Rib.

	MAN.	MONKEY.
if	$\frac{6.3}{9.50}$	$\frac{2.4}{3.70}$
then	$\frac{63}{95}$	$\frac{24}{37}$

777 to 760

7th Rib.

MAN.	MONKEY.
$\frac{34}{49}$	$\frac{2.5}{3.8}$

1292 to 1225

8th/

8th Rib.

MAN.	MONKEY.
$\frac{7.1}{10.6}$	$\frac{13}{20}$
1420	1378

9th Rib.

MAN.	MONKEY.
$\frac{6.9}{11.8}$	$\frac{6}{11}$
759	708

10th Rib.

MAN.	MONKEY.
$\frac{6.7}{12.2}$	$\frac{11}{42}$
1307	671

11th Rib.

MAN.	MONKEY.
$\frac{165}{620}$	$\frac{16.5}{6.2}$

Tabulating all these results we can see at a glance the way in which the ratio $\frac{L}{2r}$ is greater in the case of Adult Man than Monkey.

Thus/

Thus they give in : -

	MAN.	MONKEY.
1st	504	475
2nd	581	455
3rd	80	72
4th	323	308
5th	488	460
6th	777	760
7th	1292	1225
8th	1420	1378
9th	759	708
10th	1307	671
11th	620	330

Again from the table taking the ratios $\frac{L}{2r}$ in the case of the Monkey and the Full Time Foetus and comparing them we get : -

1st RIBS.

MONKEY.	FOETUS.
$\frac{.95}{1.8}$	$\frac{.5}{1.}$
$\frac{95}{180}$	$\frac{1}{2}$

190 180

Q.E.D.

2nd/

2nd RIBS.

MONKEY.		FOETUS.
$\frac{1.3}{2.8}$		$\frac{1.1}{2.4}$
$\frac{13}{28}$		$\frac{11}{24}$

312 308

3rd RIBS.

$\frac{1.8}{3.2}$	$\frac{1.3}{2.6}$
$\frac{18}{32}$	$\frac{1}{2}$

36 32

4th RIBS.

$\frac{2.1}{3.4}$	$\frac{1.45}{2.8}$
$\frac{21}{34}$	$\frac{29}{56}$

1176 986

5th RIBS.

$\frac{2.25}{3.6}$	$\frac{1.5}{3}$
$\frac{225}{360}$	$\frac{1}{2}$

450 360

6th/

6th RIBS.

MONKEY.	FOETUS.
$\frac{2.4}{3.7}$	$\frac{1.65}{3}$
$\frac{8}{37}$	$\frac{55}{300}$

2400 2035

7th RIBS.

$\frac{2.5}{3.8}$	$\frac{1.7}{3.4}$
$\frac{25}{38}$	$\frac{1}{2}$

50 38

8th RIBS.

$\frac{2.6}{4.}$	$\frac{1.8}{3.6}$
$\frac{26}{40}$	$\frac{1}{2}$

52 40

9th RIBS.

$\frac{2.4}{4.4}$	$\frac{1.65}{3.8}$
$\frac{6}{11}$	$\frac{165}{380}$

2280 1815

10th/

10th RIBS.

MONKEY.	FOETUS.
$\frac{2.2}{4.8}$	$\frac{1.3}{3}$
$\frac{22}{16}$	$\frac{13}{10}$
220	208

11th RIBS.

MONKEY.	FOETUS.
$\frac{1.65}{6.2}$	$\frac{.8}{3.4}$
$\frac{33}{62}$	$\frac{8}{17}$
561	496

In every case, therefore, we find that the ratio is greater in the Monkey than in the Foetus.

Again comparing Monkey with Full Time Foetus we obtain the following numbers : -

RIB	MONKEY	FULL TIME FOETUS.
1st	190	180
2nd	312	308
3rd	36	32
4th	1176	986
5th	450	360
6th	2400	2035
7th	50	38
8th	52	40
9th	2280	1815
10th	220	208
11th	561	496

As we saw that the ratio was greater in the case of Adult Man than Monkey, so we now see that, in every case the ratio is greater in Monkey than in Full Time Foetus.

Comparing now Full Time Foetus with 6 Months! Foetus, we find in the case of the : -

1st RIBS.		2nd RIBS.	
FULL TIME.	6 MONTHS'	FULL TIME.	6 MONTHS.
$\frac{.5}{1}$	$\frac{.4}{1}$	$\frac{1.1}{2.4}$	$\frac{.9}{2}$
i.e. 5 to 4.		$\frac{11}{6}$ to	$\frac{9}{5}$
		55 to 54.	

3rd RIBS.		4th RIBS.	
FULL TIME.	6 MONTHS.	FULL TIME.	6 MONTHS.
$\frac{1.3}{2.6}$	$\frac{1}{2.2}$	$\frac{1.45}{2.8}$	$\frac{1.2}{2.4}$
$\frac{13}{26}$	$\frac{10}{22}$	$\frac{145}{280}$ to	$\frac{1}{2}$
$\frac{1}{2}$	$\frac{5}{11}$	290 to	280
11 to 10.			

5th RIBS.		6th RIBS.	
FULL TIME.	6 MONTHS.	FULL TIME.	6 MONTHS.
$\frac{1.5}{3}$	$\frac{1.25}{2.6}$	$\frac{1.65}{3}$	$\frac{1.3}{3}$
$\frac{1}{2}$	$\frac{125}{260}$	165 to 130	
260 to 250			

7th RIBS.

FULL TIME.	6 MONTHS.
$\frac{1.7}{3.4}$	$\frac{1.4}{3.3}$
$\frac{17}{34}$	$\frac{14}{33}$

561 to 476.

8th RIBS.

FULL TIME.	6 MONTHS.
$\frac{1.8}{3.6}$	$\frac{1.5}{3.4}$
$\frac{1}{2}$	$\frac{15}{34}$

34 to 30.

9th RIBS.

FULL TIME.	6 MONTHS.
$\frac{1.5}{3.8}$	$\frac{1.3}{3.6}$
$\frac{15}{19}$	$\frac{13}{18}$

270 to 247

10th RIBS.

FULL TIME.	6 MONTHS.
$\frac{1.3}{3.9}$	$\frac{.9}{3.7}$
$\frac{1}{3}$	$\frac{9}{37}$

37 to 27

11th RIBS.

FULL TIME.	6 MONTHS.
$\frac{.8}{4}$	$\frac{.6}{3.8}$
$\frac{1}{5}$	$\frac{3}{19}$

19 to 15.

Tabulating/

Tabulating the results in the case of the Full Time Foetus, and the 6 Months' Foetus, we obtain in : -

	FULL TIME.	6 MONTHS FOETUS.
1st	5	4
2nd	55	54
3rd	11	10
4th	290	280
5th	260	250
6th	165	130
7th	561	476
8th	34	30
9th	270	247
10th	37	27
11th	19	15

We have thus shown that the ratio $\frac{L}{2r}$ is greater in Adult Man than in Monkey, in Monkey than in Full Time Foetus, in Full Time Foetus than in 6 Months' Foetus.

In/

In the case of the Ribs of the skeleton of a young child, the measures of the lengths L and r gave : -

	LENGTH OF CHORD (L)	RADIUS OF CURVATURE (r)
1st Rib.	1.1	1
2nd	2	1.7
3rd	2.45	2
4th	2.8	2.2
5th	3	2.4
6th	3.25	2.5
7th	3.4	2.55
8th	3.45	2.6
9th	3.2	2.8
10th	2.7	2.9
11th	1.6	3

We shall now see by comparing the ratio $\frac{L}{2r}$ in the case of the Adult Man, Young Child and Monkey, that the Young Child, in regard to this ratio, takes an intermediate position between that of the Adult Man and the Monkey.

1st/

1st RIBS.

ADULT MAN.	YOUNG CHILD.	MONKEY.
$\frac{2.8}{5}$	$\frac{1.1}{2}$	$\frac{.95}{1.8}$
$\frac{14}{25}$	$\frac{11}{20}$	$\frac{19}{36}$

By finding the common denominator of these three fractions to be 900, we have for our comparative numbers : -

504 to 495 to 475.

IN THE 2nd RIBS.

ADULT MAN	YOUNG CHILD.	MONKEY.
$\frac{4.15}{7}$	$\frac{2}{3.4}$	$\frac{1.3}{2.8}$
$\frac{415}{700}$	$\frac{20}{34}$	$\frac{13}{28}$
$\frac{83}{140}$	$\frac{10}{17}$	$\frac{13}{28}$

Proceeding to find the common denominator as before and comparing the numerators, we have for common denominator 16,660. This gives us in the numerators for comparison : -

9877 9800 & 7735.

In/

IN THE 3RD RIBS WE HAVE -

ADULT MAN	YOUNG CHILD	MONKEY.
$\frac{5}{8}$	$\frac{2.45}{4}$	$\frac{1.8}{3.2}$
$\frac{5}{8}$	$\frac{49}{80}$	$\frac{9}{16}$
50	49	45

4th RIBS.

ADULT MAN	YOUNG CHILD	MONKEY
$\frac{5.7}{8.8}$	$\frac{2.8}{4.4}$	$\frac{2.1}{3.4}$
$\frac{57}{88}$	$\frac{7}{11}$	$\frac{21}{34}$
969	952	924

5th RIBS.

ADULT MAN	YOUNG CHILD	MONKEY.
$\frac{6.1}{9.2}$	$\frac{3}{4.8}$	$\frac{2.25}{3.6}$
$\frac{61}{92}$	$\frac{5}{8}$	$\frac{5}{8}$
122	115	115

In this case the ratios for the Young Child and Monkey coincide.

6th RIBS.

ADULT MAN	YOUNG CHILD	MONKEY
$\frac{6.3}{9.5}$	$\frac{3.25}{5}$	$\frac{2.4}{3.7}$
$\frac{63}{95}$	$\frac{13}{20}$	$\frac{24}{37}$
9324	9139	9120

7TH RIBS.

ADULT MAN	YOUNG CHILD	MONKEY
$\frac{6.8}{9.8}$	$\frac{3.4}{5.1}$	$\frac{2.5}{3.8}$
$\frac{34}{49}$	$\frac{2}{3}$	$\frac{25}{38}$
3876	3724	3675

8TH RIBS.

ADULT MAN	YOUNG CHILD	MONKEY
$\frac{7.1}{10.6}$	$\frac{3.45}{5.2}$	$\frac{2.6}{4}$
$\frac{71}{106}$	$\frac{345}{520}$	$\frac{26}{40}$
$\frac{71}{106}$	$\frac{69}{104}$	$\frac{13}{20}$
18460	18285	17914

9th RIBS.

ADULT MAN	YOUNG CHILD	MONKEY.
$\frac{6.9}{11.8}$	$\frac{3.2}{5.6}$	$\frac{2.4}{4.4}$
$\frac{69}{118}$	$\frac{4}{7}$	$\frac{6}{11}$
5313	5192	4956

10TH RIBS.

ADULT MAN	YOUNG CHILD	MONKEY
$\frac{6.7}{12.2}$	$\frac{2.7}{5.8}$	$\frac{2.2}{4.8}$
$\frac{67}{122}$	$\frac{27}{58}$	$\frac{11}{24}$
93312	79056	77836

11TH RIBS.

ADULT MAN	YOUNG CHILD	MONKEY.
$\frac{5.7}{2x5.7}$	$\frac{1.6}{6}$	$\frac{1.65}{6.2}$
$\frac{1}{2}$	$\frac{4}{15}$	$\frac{33}{124}$
1860	496	495

We may tabulate the numbers thus:-

	ADULT MAN	YOUNG CHILD	MONKEY.
1	504	495	475
2	9877	9800	7735
3	50	49	45
4	969	952	924
5	122	115	115
6	9324	9139	9120
7	3876	3724	3675
8	18460	18285	17914
9	5313	5192	4956
10	93312	79056	77836
11	1860	496	495

We/

We come to this result, therefore, that the ratio $\frac{L}{2r}$ is greatest in the Adult human being, and then the ratio successively decreases as we go down the series through Man, Young Child, Monkey, Full Time Foetus, and 6 Months' Foetus. We may thus state the result.

In regard to the curves of the ribs, from their heads to their angles, the arcs of the circles of which these parts of the ribs severally consist, bear a greater ratio to the whole circumference of the circles of which these arcs consist, in the Adult Man than they do in the Young Child, in the Young Child than they do in the Monkey, in the Monkey than they do in the Full Time Foetus, and in the Full Time Foetus than they do in the 6 Months' Foetus.

With the above results, it is now interesting to compare the results obtained from a Foetus younger than six months, whose exact age I was unable to ascertain.

As we should expect, it falls into the series below the Six Months' Foetus. The comparison Rib by Rib with the 6 Months' Foetus will now be given.

The measurements of this Foetus (younger than 6 Months') gave:-

Curvature/

CURVATURE (r) From Head to Angle.		LENGTH IN CENTIMETRES. From Head to Angle.
1st Rib	.4	.3
2nd	.7	.55
3rd	.8	.65
4th	.9	.7
5th	1	.75
6th	1.1	.85
7th	1.2	.9
8th	1.3	.95
9th	1.4	.8
10th	1.5	.7
11th	1.6	.5

Comparing the 1st Ribs with those of the 6 Months' Foetus, in respect to the ratio $\frac{L}{2r}$ we get -

	6 MONTHS' FOETUS	YOUNGER THAN 6 MONTHS.
	$\frac{.4}{1}$	$\frac{.3}{.8}$
i.e.	$\frac{2}{5}$	$\frac{3}{8}$
	16	15

2nd RIBS.

$\frac{.9}{2}$	$\frac{.55}{1.4}$
$\frac{9}{20}$	$\frac{11}{28}$
252 to	220.

3rd/

3rd RIBS.

6 MONTHS' FOETUS	YOUNGER FOETUS.
$\frac{1}{2.2}$	$\frac{.165}{1.6}$
$\frac{5}{11}$	$\frac{13}{32}$

160 to 143

4th RIBS.

$\frac{1.2}{2.4}$	$\frac{.7}{1.8}$
$\frac{1}{2}$	$\frac{7}{18}$

18 to 14

5th RIBS.

$\frac{1.25}{2.6}$	$\frac{.75}{2}$
$\frac{25}{52}$	$\frac{3}{8}$

200 to 156

6th RIBS.

$\frac{1.3}{3}$	$\frac{.85}{2.2}$
$\frac{13}{30}$	$\frac{17}{44}$

572 to 510

7th RIBS.

6 MONTHS' FOETUS.	YOUNGER.
$\frac{1.4}{3.3}$	$\frac{.9}{2.4}$
$\frac{14}{33}$	$\frac{3}{8}$

112 to 99

8TH RIBS.

$\frac{1.5}{3.4}$	$\frac{.95}{2.6}$
$\frac{15}{34}$	$\frac{19}{52}$

780 to 646

9th RIBS.

$\frac{1.3}{3.6}$	$\frac{.8}{2.8}$
$\frac{13}{36}$	$\frac{2}{7}$

91 to 72

10TH RIBS.

$\frac{.9}{3.7}$	$\frac{.7}{3}$
$\frac{9}{37}$	$\frac{7}{30}$

270 to 259.

11TH RIBS. /

11th RIBS.

6 MONTHS' FOETUS	YOUNGER FOETUS.
$\frac{.6}{3.8}$	$\frac{.5}{3.2}$
$\frac{3}{19}$	$\frac{5}{32}$
96 to 95	

Arranging the numbers in a Table as before we get for the comparison : -

	6 MONTHS' FOETUS.	YOUNGER FOETUS.
1st Rib.	16	15
2nd	252	220
3rd	160	143
4th	18	14
5th	200	156
6th	572	510
7th	112	99
8th	780	646
9th	91	72
10th	270	259
11th	96	95

The Younger Foetus therefore, falls into series, as we should expect it to do, from the previous results, behind the 6 months' foetus.

These results may be put graphically thus, as in Fig. 16

Six circles are drawn with centre O. The six chords MN, KL, GH, EF, CD, and AB, cut off, arcs/

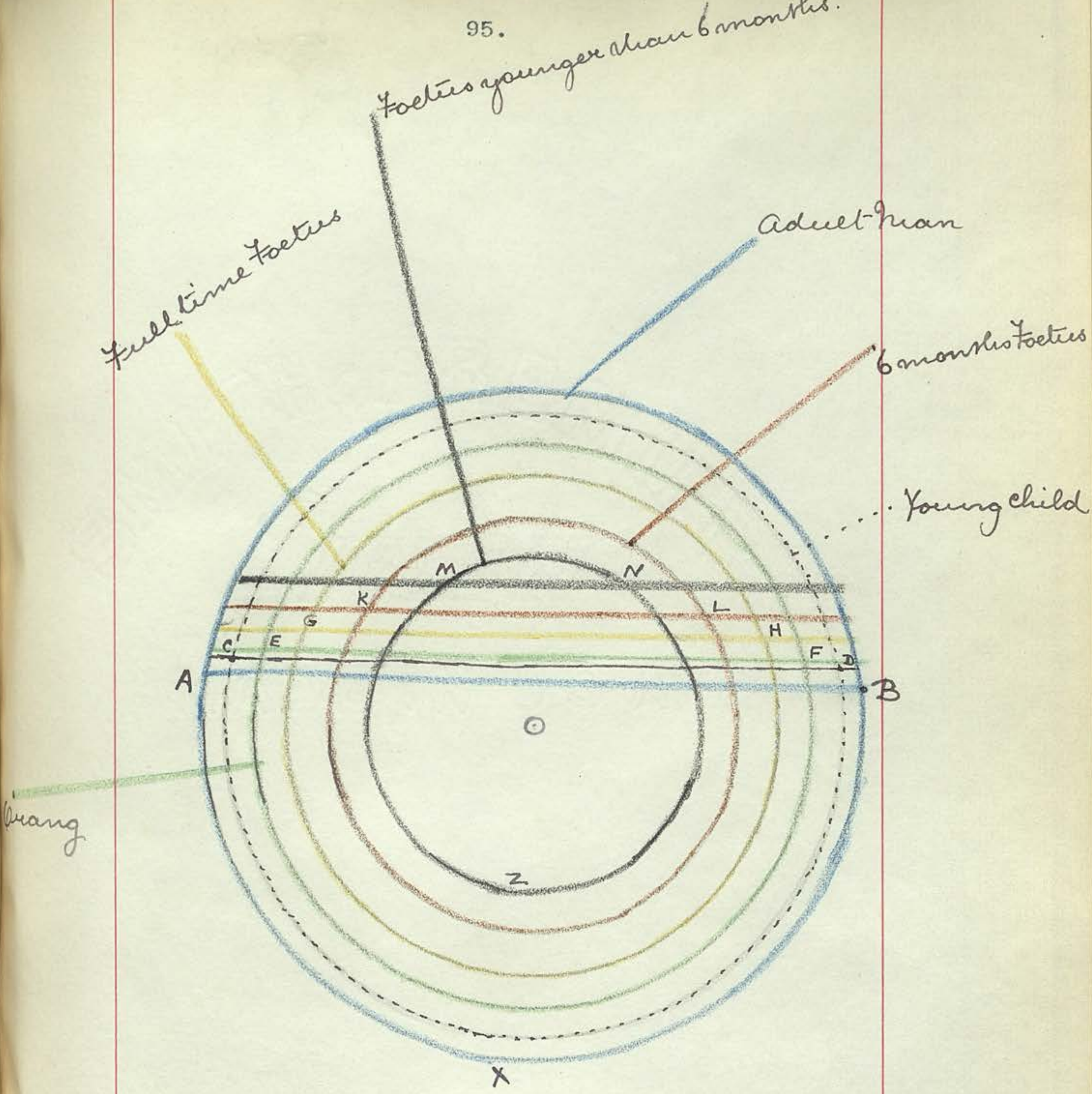

fig. 16.
Illustrating the relations of the arcs to the circles of which they form parts, in the case of the ribs of the various specimens

82
p.p. 75a.

arcs of these circles which represent respectively the curves of any rib from its head to its angle in Foetus Younger than six Months, 6 Months' Foetus, Full Time Foetus, Monkey, Young Child, and Adult Man. Thus the arc MN., is the amount of the circumference of the smallest circle MNZ, which is used up in forming the part of the rib, in the Foetus Younger than 6 Months, from its Head to its Angle.

Similarly, the arc from K to L represents the corresponding part of the rib in the case of the 6 Months' Foetus. Finally AB is the arc of the largest circle ABX (in blue) used up in forming this part of the rib in the Adult Man. If there had been similar portions of the circles used up in all cases, then the line MN continued as in the Figure, both ways, so as to cut all the circles, would have cut off the corresponding arcs.

We see, however, that as we descend in the scale from the Adult Man to the Youngest Foetus, that there is less and less of the circle, whose radius corresponds to the curvature of part of the Rib, (from its head to its angle) used up in forming this part of the Rib.

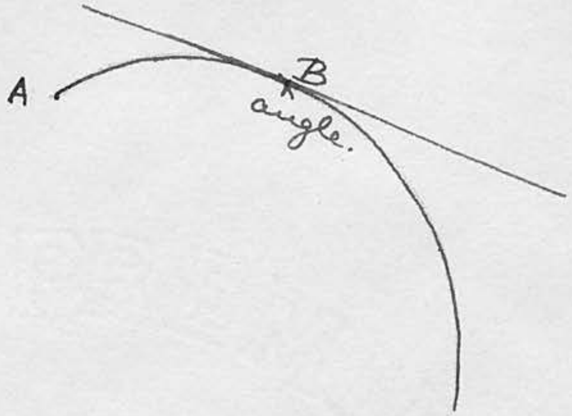

fig. 17.

This figure shows that at B, where the first change of curvature takes place, the two arcs which form the rib through this part of its course, would have a common tangent, if there were no angle.

THE ANGLES OF THE RIBS.

Outside the tuberosity, over the most convex part of the body, is a rough line which corresponds to the outer border of the erector spinae muscle, and marks the angle, so called because at this point the rib takes a more sudden curve, its direction being now forwards and outwards. (1)

We have seen that the first change of curvature occurs at this point, but this is not all.

If this change of curvature was all the change that occurred at the 'angle', we should then, as in the figure, 17 have the two curves A.B. and BC, (if ABC be a Rib, A its head, and B its angle) with a common tangent at B. and the curvature of the Ribs, though changed at B., would be continuous and there would be no angle. We shall see that there is an angle. The position of B. would then depend on the curvature of the first part of the rib, from the head to the angle, and also on the inclination of the tangent to the rib, at its head, to the antero-posterior diameter of the chest drawn through the head of/

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(1) Quain. Osteology p.26 Vol.II Part I.

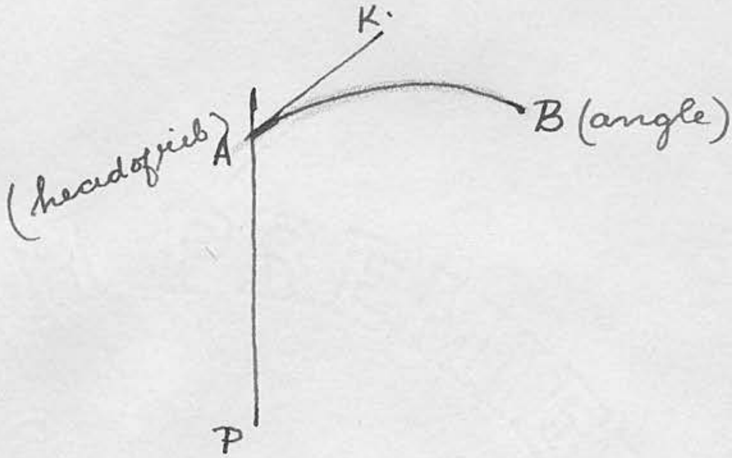


fig. 18.

AP is the antero-posterior diameter drawn through the head of the rib.

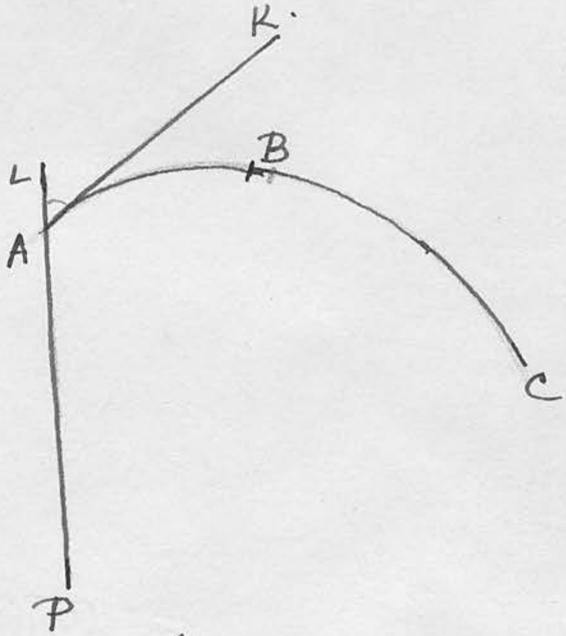


fig. 19.

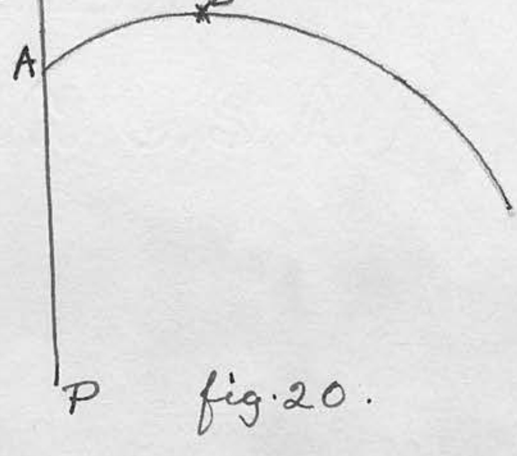


fig. 20.

In fig. 20 the tangent A K is shown coinciding with the antero-posterior diameter A P.

of the Rib. fig. 18.

AK being the tangent at A to the Rib and AP the antero-posterior diameter of the Rib.

THE CHANGES IN THE POSITION OF THE RIB FROM ITS HEAD TO JUST BEYOND THE ANGLE.

The study of the Rib in this part of its course is important, because it is into this bend of the Rib, from its head to its angle, and just beyond, that the lung expands on inspiration. This bend makes up to a certain extent for the antero-posterior flattening of the adult human chest wall.

If AP be the antero-posterior diameter of the Chest, through the head of the Rib, and AB be the first part of the Rib to its angle B & BC, the next arc of the rib, then the curve AB may a priori, be placed so that its tangent

AK at A may make any angle between 0° and 90° with the antero-posterior diameter AP. fig. 19

Thus in Fig. ~~11~~ 20. the tangent at A to the Rib coincides with the antero-posterior diameter of the chest through A (AP).

Again/

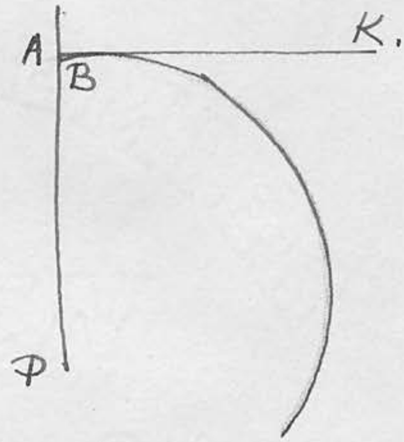


fig. 21.

The angle B is represented here as coinciding with the head (A) of the rib.

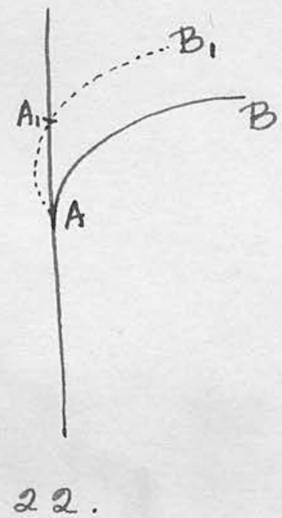


fig. 22.

This shows the head of the rib (A) displaced backwards to A_1

Again in Fig. 21 it might have been so placed that its tangent AK is at right angles to the antero-posterior diameter AP.

In this latter case, in order to fulfil the description that the rib Curves backwards to its angle, the angle would now coincide with the head of the Rib.

Figs. 20 and 21 show the two extreme positions in which the first arc of the rib might have been placed. If the rib were placed so as to make a negative angle with the antero-posterior diameter through the head of the Rib, i.e. considering the angles measured from left to right in the figure to be positive, and from right to left to be negative, we should get a position such as is indicated in the Fig. 22. AB_1. This is, of course, impossible, for then with the same curvatures as before we should have the head of the Rib displaced backwards to A_1, and, moreover, B_1 would not be the most posterior part of the Rib.

Again, if the Rib were placed beyond the 2nd limiting position, as indicated in Figure 21, then we should get a position, as indicated in Fig. 23. the tangent AK now sloping forwards, and the Rib not turning backwards at all.

Again in regard to the next arc of the rib from/

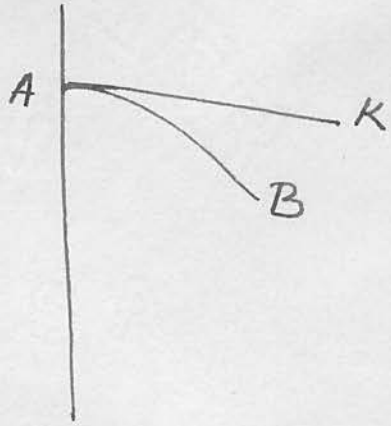


fig. 23.

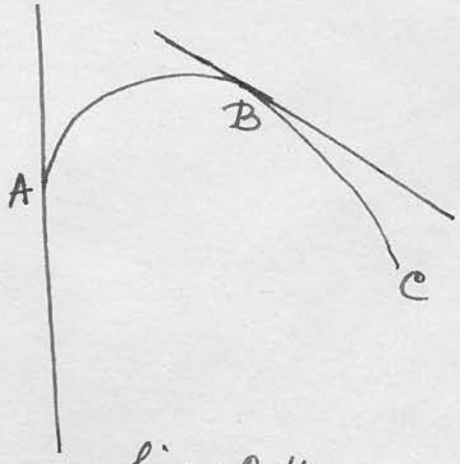


fig. 24.

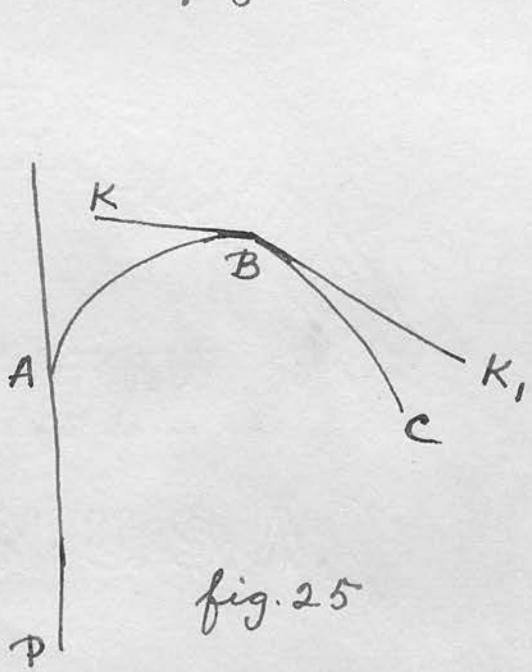


fig. 25

from the angle onwards, the two arcs might be so placed, that they have a common tangent at the angle B. as in Fig. ~~VI~~ 24., or again, the two segments may be so placed, that the tangents to each of them at the angle enclose an angle between them, as in Fig. ~~VII~~ 25.

BK being the tangent to the first segment, and BK_1 being the tangent to the second segment.

As before, the limits of this angle enclosed by the two tangents would be 0° and 90°, as shown in Figs. ~~VII~~ 25 and ~~VIII~~ 26.

As a matter of fact, I find that the arcs of the Rib are so joined at the angle that the two tangents do include between them an angle. So that we arrive at this conclusion that : -

(1) The tangent to the first arc of the Rib, i.e. the part between the head and the angle, at its head, is inclined at an angle between 0° and 90° to the antero-posterior diameter of the chest through the head of the Rib.

(2) The first two arcs of the Rib are joined together at the 'angle' so that their tangents enclose an angle between them.

We may thus define the angle of the Ribs

as/

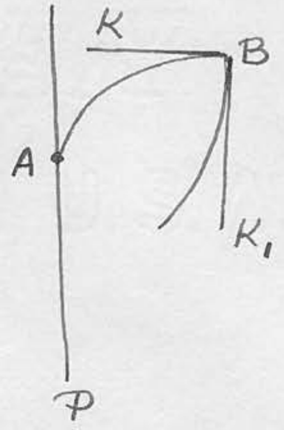


fig. 26.

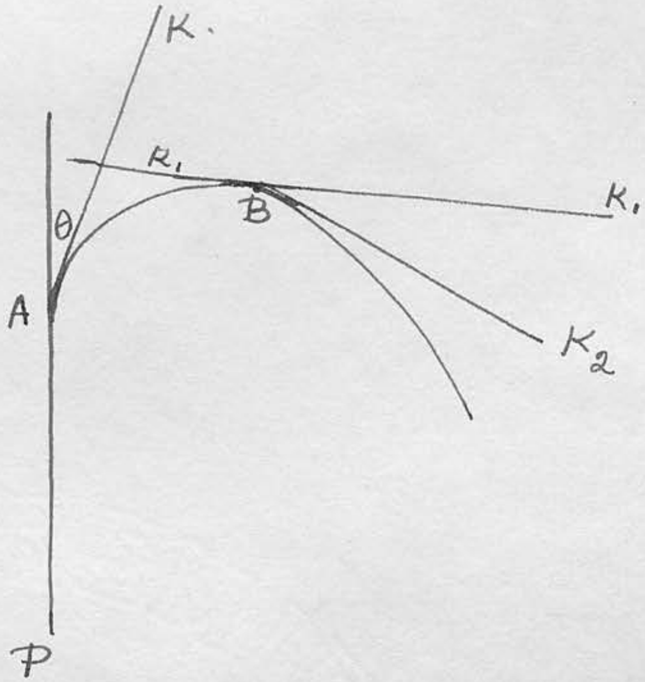


fig. 27.

This figure shows the actual relationship of the first two arcs of a rib to each other at the angle B, & also the relation of the first arc AB to the antero-posterior diameter AP.

as the point where the first two arcs of the Rib (of dissimilar radius) are joined together, in such a way that they have not a common tangent, but their tangents at this point make an angle with each other.

The exterior of the Rib at this point is marked by a ridge of bone which corresponds to the outer border of the erector spinae muscle.

As in the Fig. ~~1X~~ 27. AP is the antero-posterior diameter of the Chest, through the head A of the Rib.

AK is the tangent at A to the rib, making the angle θ with AP
BK_1 is the tangent at B to the first segment AB (the 'angle')
BK_2 is the tangent at B to the second segment BC.

Between these two tangents we have the angle θ which is really 'the angle'.

I find the angle is greatest in the Adult Man, and that again in regard to the size of the angle, we have a descending Series from the Adult Man, down to the youngest Foetus.

The /

The following is the Table of Angles:-

RIB	ADULT	MONKEY	FULL TIME FOETUS.	6 MONTHS' FOETUS.	YOUNGEST FOETUS.
1st	13°	5°	6½°	9°	5°
2nd	15°	13°	11½°	10°	6°
3rd	17°	15°	12°	10½°	7°
4th	20°	15°	13°	11°	8°
5th	23°	17°	14½°	12°	11°
6th	25°	17°	16½°	14°	11°
7th	25°	20°	18°	15°	13°
8th	30°	20°	18°	15°	13°
9th	25°	17°	12½°	15°	12°
10th	17½°	14°	11°	11°	8½°
11th	13°	10°	9°	7°	5°

We notice that the angle follows the same rule under all the headings. It appears to increase up to the 8th, and then gradually decreases down to the 11th. The angles of the first and 2nd Ribs in the Monkey were proportionally less than the rest of its angles when compared with the others.

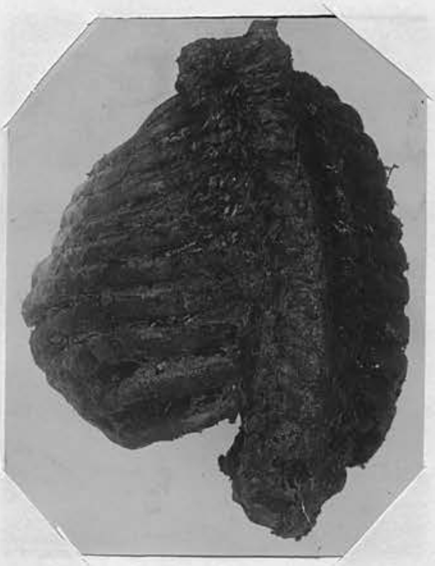
From the gradual diminution in size of the angle, one might expect that, if we could obtain and measure foetuses in the very earliest stages of rib formation/

formation, we should find no angle at all.

The fact that the very youngest foetus measured, shows a distinct angle, long before it is physiologically justified, presents no difficulty as regards inheritance. Moreover, accepting the view that the angle is due to the erect posture, we have a good explanation of the table. The Full Time Foetus, in regard to its angle, falls well behind the Monkey: but then the posture of the Monkey quite easily accounts for the difference between its angles and those of the Full Time Foetus.

Again, that perfectly erect posture of the Adult Man explains the difference between his angles and those of the Monkey.

Again, accepting this view as to the origin of the angle, the two chief factors in producing it are (1) The Erector spinae mass, and (2) The expansion of the lungs backwards.



FULL TIME FOETUS, showing the horizontal direction of the ribs and crowding together of the upper ribs, with consequent narrowing of the upper intercostal spaces.

THE INCLINATION OF THE RIBS to THE VERTEBRAL COLUMN.

All the ribs in the Adult Man slope downwards from the spine. They are placed that the anterior end of one rib is on a level with the posterior end of a rib some way below it in numerical order. Thus the anterior end of the 4th rib is on the same level as the posterior end of the 7th, and generally the anterior end of a given rib lies opposite to the posterior end of the rib three lower down in the series. (1)

If the disarticulated ribs are placed in order on a table lying on their lower edges, then the first rib is seen to be practically flat. There is however, a slight bending of the head downwards, owing to a bend in the first part of the rib, which has its convexity situated at the angle.

The curve in the vertical plane is not a uniform one. In this plane, just as in the horizontal plane, the curvature of the ribs varies as we proceed from the head to the end of the bony rib. These differences/

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(1) Miles & Thompson's Surgery. (Edinr. 1904)

differences of curvature in the vertical plane give rise to the appearance that the rib is 'twisted' on itself, or as it is sometimes called has a 'torsion'.

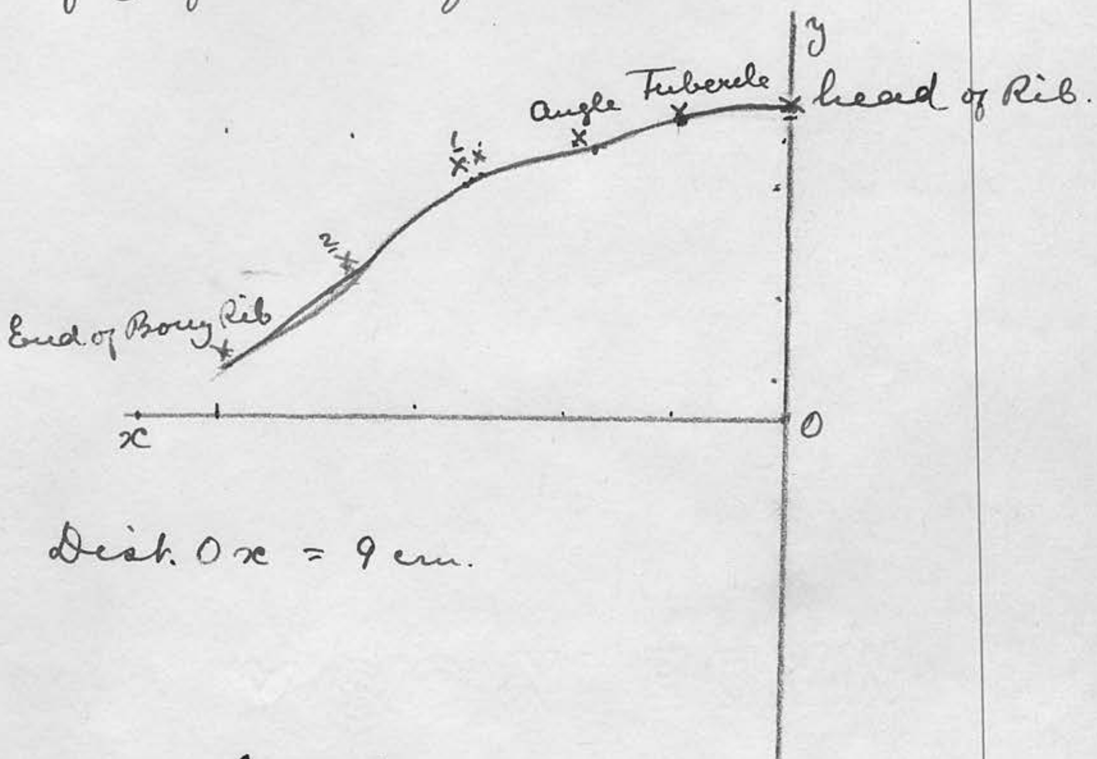
As was remarked above, if the ribs are placed in order on a table, lying on their lower edges, the 2nd & 3rd ribs like the first are seen to have a slighter inclination of their heads downwards than the first. The head of the 4th rib is curled a little upwards, so as not to touch the table, when the bone is placed upon its lower edge.

This inclination upwards of the head now is seen to increase up to the 7th rib, and then again diminishes to the 12th rib, the head of which like that of the 3 upper ribs, is slightly inclined downwards.

Thus, when the several ribs rest upon their lower edges, a line drawn through their heads would be a curve whose highest point was at the 7th rib. On the other hand, the anterior extremities of the ribs are all inclined downwards; the least inclination being noticed in the 1st & 12th ribs and the greatest in the 7th, 8th, 9th & 10th.

In order to show the inclinations of the ribs in the vertical plane, I projected the ribs on to a vertical plane, and then measured the distances of/

Curve of the 6th Rib in the Vertical plane. Reduced to scale of $\frac{1}{3}$ of the original measurements.



Dist. 0x = 9 cm.

fig. A.

of the ribs at definite points along its length from a horizontal axis drawn through the highest point of the rib.

Thus, for example, in a typical 6th rib, the projecting it on to a vertical plane, if Ox & Oy fig. A. be the axes in this plane, passing through O in this case the middle point of the head of the rib, I found that as one proceeded from the head to the end of the bony rib the measurements downwards from the horizontal axis through the head of the rib were in centimetres : -

HEAD.	TUB.	ANGLE.	I	2	END of BONY RIB.
0	.3	1.4	3.5	7	11.3

It will be thus seen that there was a very small fall between the head and the Tubercle, somewhat greater fall from the Tubercle to the angle and then the fall increased in an increasing ratio as one proceeds to the end of the bony rib.

The readings under the headings I, 2 & End of Bony Rib were obtained by dividing the Rib from its angle to the end of the Bony Rib into thirds and taking the downward displacement at the end of each third of the rib. This is shewn in the accompanying fig.A where the above measurements have been reduced to the scale/

scale of 1/3 of the original. The measurements were taken from a point midway between the upper & lower borders of the Ribs.

It will be seen from fig. A that the curve of the rib in the vertical plane is not uniformly downwards. From the head to the angle it is a curve with its convexity upwards. From the angle to a point 2/3 of the distance from the angle to the end of the bony rib, it is another curve with its convexity upwards, whilst from the last point to the end we have another very slightly convex curve.

By proceeding in this way, it was found that in the case of the first five ribs, by measuring from a point midway between the upper & lower borders of the rib, that the Tubercle was the highest point of these ribs: the angle somewhat lower and the head lower than the angle. Then by dividing the rib from the angle to the end of the rib into thirds, the point situated at the first third was at a somewhat lower level than the head: the point at the 2nd third lower still, and the end of the bony rib lowest of all.

In the case of the 6th to the 12th ribs, the highest point was found to be situated at the head of the rib. This will be seen from the following table.

Projection of the Ribs of a Human Adult on to a Vertical Plane, and the distances from a horizontal axis through the highest point of each of the ribs of fixed points along the rib.

	HEAD.	TUB.	ANGLE.	I	2	END of BONY RIB.
1	.9	0	.3	1	2.8	4.1
2	1.4	0	.5	2.7	4	6.7
3	.8	0	.5	1.2	3.6	7.1
4	1.5	0	.6	2	5	9.7
5	1.5	0	.5	2.5	6.2	11
6	0	.3	1.4	3.5	7	11.3
7	0	.8	1.5	3.5	8	12
8	0	1.2	3	5	8	12.6
9	0	1.8	4	8	11	13.5
10	0	.9	3.9	3	6	9.8
11	0					9.8
12	0					4.

The above measurements are in centimetres and each rib was measured separately, with reference to an axis drawn through its highest point.

It will be at once seen from the measurements of the projection on the vertical plane just given that the point of the rib which is situated $^1/_3$ of the distance from the angle to the end of the bony rib, i.e. about the middle of the rib, is, in the human Adult invariably at a considerably lower level than the angle of the rib.

In the case of the first rib, it is only 9 cm. lower but in all the rest it is at a considerably lower/

Photograph of a Six Months' Foetus, showing the crowding together of the upper ribs, especially just beyond their angles.

lower level.

The case is quite different when we come to the Monkey & the Foetus. In fact, one of the very noticeable things about the thoraces of the Monkey & Foetus is the crowding together of the upper 6 or 7 ribs, especially just beyond their angles.

For the sake of comparison the following measurements were taken : -

Downward slope of the Ribs in the Orang-outang shown by projecting the ribs on to a vertical plane and referring them to a horizontal axis drawn through the angles of the 6th Ribs and a vertical axis at right angles to this passing through the head of the first rib.

MEASURED/

MEASURED IN CENTIMETRES.

RIB.		HEAD.	TUBERCLE.	ANGLE.	
1st	x	0	.6	1.2	
	y	4.7	4.6	4.4	
2nd	x	1	1.7	3.4	3
	y	3.9	3.5	3.4	3.4
3rd	x	1	2.1	3.4	3.7
	y	2.8	2.8	2.3	2.1
4th	x	.7	2.1	3.3	4.3
	y	1.8	1.6	1.1	.9
5th	x	.8	2.1	4.2	5.6
	y	.7	.6	.5	1.1
6th	x	.7	2.1	4.3	5.6
	y	0.	-.2	-.9	-1.1
7th	x	.5	2.3	4.9	6.4
	y	-1.2	-1.4	-2.9	-2.7
8th	x	.7	2.3	4.6	6.8
	y	-2	-3	-3.6	-4.5
9th	x	.7	2.8	5.1	7.1
	y	-3.2	-4.5	-5.4	-5.8
10th	x	.8	2.5	4.5	7.1
	y	-4.6	-5.5	-6.5	-7.8
11th	x	.3	1.3	2.3	4.1
	y	-5.3	-6	-6.8	-8.7

Pieces of thread were stretched between two pins in the manner indicated in the figure opposite, to which as axes the ribs were referred.

Distances along Oy & Ox, as in ordinary co-ordinate geometry were considered positive and distances measured along and in the directions of Ox^1 & Oy^1 negative.

Thus in the table just given the measurement in connection with the 6th rib, under the leading tubercle we find $\frac{2.1}{-.2}$.

This/

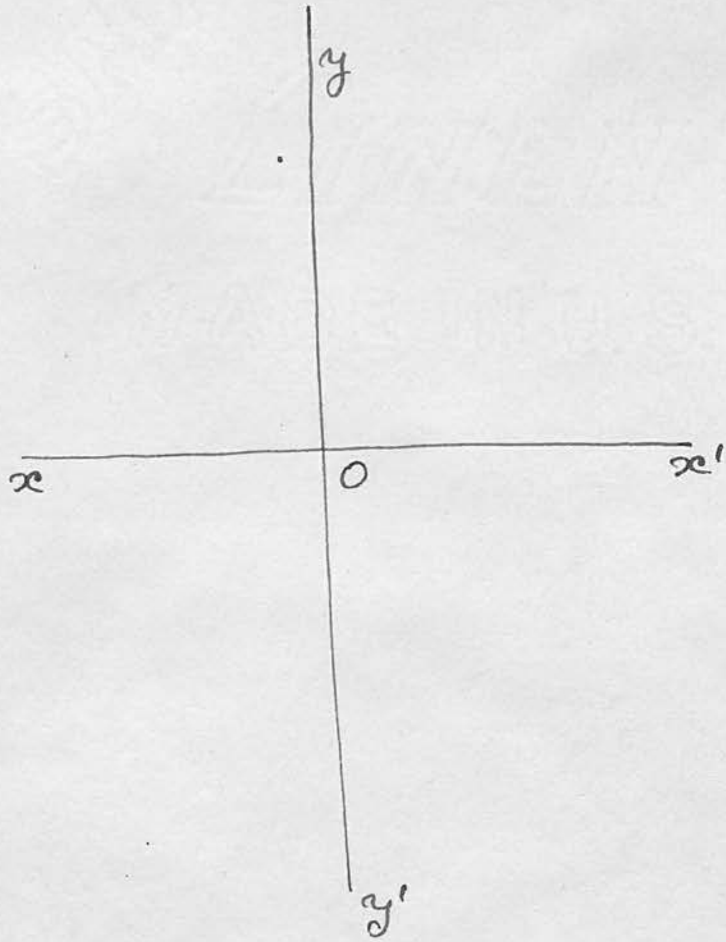


fig. 28.

The ribs were projected on to a vertical plane & then referred to the two axes x O x' & y O y' at right angles to each other in this plane.

This means that a horizontal distance = 2.1 cm. in the direction Ox, the vertical distance of the Tubercle was .2 cm. in the direction Oy^1, i.e. it lay 2 cm. below the horizontal line xox^1.

The ribs were referred in this case to axes at the level of the angles of the 6th Ribs because of the narrowness of the upper part of the Thorax of the Monkey, and thus the impossibility of getting the threads stretched horizontally & vertically without their being touched by the projecting cut ends of the ribs.

The front half of the thoracic wall had been removed from the specimens and being hardened in formation, could be lifted off like a lid.

The measures in the last row were taken at a distance from the spine horizontally equal to that of the end of the 8th rib. The front of the chest wall in the monkey was cut, as mentioned above, at this level.

Again in this table two measures of every point measured on the ribs were taken, so as to fix the point in the vertical plane absolutely, and thus make the comparison with the Foetus absolute. The numerator of the fraction under each heading is the horizontal/

horizontal distance of the point measured along Ox & in that direction ; the denominator is the distance along and in the direction of Oy if positive, and along and in the direction of Oy^1 (i.e. from O towards y^1) if negative.

Thus taking the 4th rib $\frac{X}{y}$ in the first column means that the numerators of all the fractions in this row are distances measured in the x direction, i.e. along Ox, and therefore show how far out from the origin, in a horizontal direction, the point is situated, whereas the denominators of all the fractions show the distance up if positive, and down if negative, that the point under consideration is, along and in the direction of Oy if positive and Oy^1 if negative.

So that, under the vertical column, at the top of which is 'Head', we see in the case of the 4th rib, that the head of the rib is at a distance 7 cm. in the horizontal direction from the origin chosen and that it is also at a distance 1.8 cm. from the origin in the direction Oy.

The measurements giving the projection on to a vertical plane, of the Full Time Foetus are : -

RIB/

RIB.		HEAD.	TUB.	ANGLE.	I.	2.	END of BONY RIB.
1st	x	0	.4		1.5	1.5	1.1
	y	0	.2		.1	0	-.5
2nd	x	.1	.5	1.	2.	2.1	1.
	y	.5	.4	.4	.7	.9	.5
3rd	x	0	.4	1.3	2.5	2.7	1.2
	y	1.05	1.05	1.1	1.2	1.2	.1
4th	x	0	.4	1.3	2.4	2.3	1.35
	y	1.3	1.3	1.6	1.8	1.8	1.5
5th	x	.1	.6	1.4	2.4	2.35	1.6
	y	1.8	1.85	1.9	2.2	2.4	2.3
6th	x	.15	.65	1.6	2.45	2.45	2
	y	2.3	2.5	2.7	2.75	2.8	3
7th	x	.2	.7	1.65	2.5	2.7	2.6
	y	2.9	3.2	3.5	3.4	3.5	4.
8th	x	.2	.7	1.7	2.6	2.8	2.8
	y	3.5	3.8	4.15	4.	4.2	4.5
9th	x	.15	.6	1.6	2.5	2.75	2.9
	y	4.25	4.4	4.9	4.9	5.	5.1
10th	x	.15	.5	1.4	2.3	2.65	2.9
	y	4.8	5.1	5.5	6.	6.1	6.2
11th	x	.15	.5	1.15	2.	2.5	2.55
	y	5.5	5.8	6.3	6.4	6.7	7.

The measurements are made in centimetres and refer to axes of origin Ox & Oy at right angles to each other and having their origin at the head of the First Rib.

The measurements in the case of a Six Months'/

SIX MONTHS' FOETUS. The sternum has been removed to show the shallow recesses on either side of the Spinal Column, compared with what obtains in the adult Man.

Months' Foetus gave : -

RIB. $\frac{X}{y}$	HEAD.	NECK.	TUB.	ANGLE.	I.	II.	END OF BONY RIB.
1st	$\frac{0}{0}$	$\frac{.3}{.2}$	$\frac{.4}{.3}$		$\frac{1.2}{1.3}$		$\frac{1}{1.5}$
2nd	$\frac{0}{.4}$	$\frac{.3}{1}$	$\frac{.4}{1.1}$	$\frac{1.5}{1.2}$	$\frac{1.3}{2.1}$	$\frac{1.7}{3.4}$	$\frac{1.2}{3.7}$
3rd	$\frac{-.1}{.8}$	$\frac{.1}{.8}$	$\frac{.2}{.9}$	$\frac{.5}{1.1}$	$\frac{1.3}{2.1}$	$\frac{1.7}{3.4}$	$\frac{1.2}{3.7}$
4th	$\frac{-.1}{1.3}$	$\frac{0}{1.4}$	$\frac{.3}{1.5}$	$\frac{.6}{1.6}$	$\frac{1.3}{2.5}$	$\frac{1.8}{4}$	$\frac{1.2}{4.4}$
5th	$\frac{-.1}{1.8}$	$\frac{0}{1.8}$	$\frac{.1}{1.9}$	$\frac{.7}{2.2}$	$\frac{1.3}{2.8}$	$\frac{1.9}{4.2}$	$\frac{1.4}{5.5}$
6th	$\frac{-.1}{2.1}$	$\frac{0}{2.2}$	$\frac{.1}{2.3}$	$\frac{.9}{2.4}$	$\frac{1.3}{3.4}$	$\frac{2}{5}$	$\frac{1.3}{6.9}$
7th	$\frac{-.1}{2.7}$	$\frac{.1}{2.8}$	$\frac{.2}{2.9}$	$\frac{1.}{3.2}$	$\frac{1.3}{3.8}$	$\frac{1.9}{5.7}$	$\frac{1.3}{7.1}$
8th	$\frac{-.1}{3.3}$	$\frac{.1}{3.4}$	$\frac{.3}{3.5}$	$\frac{1.2}{3.8}$	$\frac{1.3}{4.5}$	$\frac{2.}{6.1}$	$\frac{1.4}{7.}$
9th	$\frac{-.1}{3.8}$	$\frac{0}{4}$	$\frac{.1}{4.1}$	$\frac{1.1}{4.6}$	$\frac{1.3}{5.5}$	$\frac{2}{6.1}$	$\frac{1.5}{7.2}$
10th	$\frac{-.1}{4.4}$	$\frac{0}{4.5}$	$\frac{.1}{4.6}$	$\frac{.7}{5}$	$\frac{1.3}{6.1}$		$\frac{1.5}{7.3}$
11th	$\frac{-.2}{5}$	$\frac{.1}{5.1}$	$\frac{0}{5.2}$	$\frac{.3}{5.4}$	$\frac{1.3}{7.2}$		$\frac{1.4}{7.3}$

The crowding together of the upper ribs is well shown by taking the figures under column headed I. and subtracting the denominators, i.e. the distances measured in the Oy direction, we get .4, .4, .4, .3, .6, .4, .7, 1.0, .7, 1.1. This shows the lower ribs at this place just beyond their angles to be farther apart.

The/

FOETUS younger than 6 months referred to as "Youngest Foetus" in the Text. Shows the ribs more horizontally directed than in the adult, also the shallowness of the fossae on either side of the spine for the erector spinae muscles. Moreover the angle was very small and the ribs showed fewer changes of curvature than any of the older foetuses.

The measurements in the case of the youngest Foetus gave : -

RIB. $\frac{x}{y}$	HEAD.	NECK.	TUB.	ANGLE.	I	2	END OF BONY RIB.
1st	$\frac{0}{0}$	$\frac{.1}{0}$	$\frac{.15}{0}$		$\frac{.7}{.5}$		$\frac{.7}{.6}$
2nd	$\frac{.1}{.1}$	$\frac{.15}{.1}$	$\frac{.2}{.15}$	$\frac{.35}{2}$	$\frac{.8}{.65}$	$\frac{1.2}{.9}$	$\frac{1}{1}$
3rd	$\frac{.1}{.2}$	$\frac{.15}{.25}$	$\frac{.2}{.3}$	$\frac{.4}{.5}$	$\frac{.8}{.8}$	$\frac{1.4}{1.1}$	$\frac{1.3}{1.2}$
4th	$\frac{.15}{.4}$	$\frac{.2}{.5}$	$\frac{.25}{.55}$	$\frac{.45}{.55}$	$\frac{.8}{.95}$	$\frac{1.5}{1.4}$	$\frac{1.4}{1.4}$
5th	$\frac{2}{.75}$	$\frac{.25}{.8}$	$\frac{.3}{.85}$	$\frac{.65}{1.2}$	$\frac{.8}{1.2}$	$\frac{1.6}{1.6}$	$\frac{1.8}{1.8}$
6th	$\frac{.2}{.85}$	$\frac{.25}{.85}$	$\frac{.3}{.9}$	$\frac{.7}{1.4}$	$\frac{.8}{1.4}$	$\frac{1.2}{2.1}$	$\frac{1.2}{2.2}$
7th	$\frac{.1}{1.3}$	$\frac{.15}{1.35}$	$\frac{.2}{1.4}$	$\frac{.75}{1.7}$	$\frac{.8}{1.75}$	$\frac{1.5}{2.2}$	$\frac{.9}{2.7}$
8th	$\frac{.1}{1.6}$	$\frac{1.5}{1.65}$	$\frac{.2}{1.7}$	$\frac{.75}{.2}$	$\frac{.8}{2.1}$	$\frac{1.35}{2.4}$	$\frac{.8}{2.9}$
9th	$\frac{.1}{2}$	$\frac{1.5}{2.05}$	$\frac{2}{2.1}$	$\frac{.55}{2.2}$	$\frac{.8}{2.35}$	$\frac{1.15}{2.65}$	$\frac{.6}{3.2}$
10th	$\frac{.1}{2}$	$\frac{1.5}{2.35}$	$\frac{2}{2.4}$	$\frac{.5}{2.5}$	$\frac{.8}{2.7}$	$\frac{.9}{3}$	$\frac{.5}{3.5}$
11th	$\frac{.1}{2.55}$	$\frac{1.5}{2.6}$	$\frac{2}{2.65}$	$\frac{.45}{2.8}$	$\frac{.8}{3.3}$		$\frac{.35}{3.7}$

By taking the denominators of the series of figures under the heading I. and subtracting them in turn e.g. the first from the second, .5 from .65 = .15 then the 2nd from the 3rd and so on to the end of the series, we obtain the following differences .15, .15, .15, .25, .2, .35, .35, .25, .35, .6.

This series shows the tendency to increase from about the middle of the ribs to the last rib. Remembering that these denominators give the distances down/

down from the axis of x, we see at once that as we get to the lower ribs, the distance between the ribs increases. The upper rib shews the crowding together which we have previously shown to be characteristic of the thoraces of the Monkey and the Foetuses.

These results are best exhibited by means of a figure. The slope of any rib compared with any other can however at once be seen by taking the denominators in any one column, and comparing them with the denominators in another column when it will be seen that in the case of the Monkey & Foetuses, the upper ribs are permanently less sloped than the corresponding ribs in the Adult. In fact, in the former the ribs are permanently in what is a position of expiration in the Human Adult.

THE INTERCOSTAL SPACES.

The Intercostal Spaces in the Adult Human Being filled by the intercostal muscles & aponeuroses and containing the intercostal vessels and nerves, vary in width in different parts of the chest, and at different periods of the respiratory act. Modifications of the chest also cause great alterations in the distance between the ribs. The 2nd, 3rd, 10th and/

and 11th interspaces are, in a well formed chest; the widest part of any individual space is near the anterior part of the bony rib.

The anterior ends of the intercostal spaces show a tendency to become pointed. This is however not the case in the 2nd space, and is only slightly marked in the 1st, 3rd & 4th interspaces. It is very marked in the 6th, 7th, 8th & 9th interspaces, some or all of which are completely interrupted by the interchondral articulations.

The ribs become more nearly horizontal during inspiration than during expiration. Extension of the spine widens the intercostal spaces, flexion of it contracts them. Lateral bending widens those on one side and contracts them on the other.

In order to bring out more fully this crowding together of the upper ribs just beyond their angles especially in the Foetus & Monkey, I shall now give the measures of the Intercostal Spaces in all specimens.

IN/

IN AN ADULT MAN.

RIB.	HEAD.	NECK.	TUB.	ANGLE.	I.	2.	END of RIB.
1st	.7	1	1.1	.7	.9	1.7	2.2
2nd	1.2	1.7	1.7	.9	.7	.6	2.5
3rd	.8	1	1.3	1.2	1.1	.9	2.4
4th	1.1	1.2	1.3	1.1	.9	.8	2.3
5th	.8	1.1	1.3	1.3	1		1.8
6th	.8	1.3	1.3	1.5	.9		2.2
7th	1	1.6	1.6	1	.9		1.5
8th	1	1.1	1.2	.8	.8		1.5
9th	.9	1	1.4	1.4	1.7		1.5
10th	2	2.2	2.7	1.4	1.8		2.5
11th	2.3	2.7	2.6	2.8			2.6

The measures under Head, Neck, Tubercle etc. are taken opposite the Head, Neck, Tubercle etc. of the uppermost of the two ribs bounding an intercostal space.

IN/

IN THE ORANG.

RIB.	NECK.	TUB.	ANGLE.	I.	2.	END of BONY RIB.
1st	.55	.5	.5	.55	.65	.7
2nd	.6	.5	.35	.4	.65	.9
3rd	.5	.4	.3	.4	.6	.8
4th	.4	.35	.2	.35	.6	.7
5th	.4	.3	.2	.3	.5	.8
6th	.4	.3	.27	.4	.9	1.1
7th	.4	.45	.4	.7	1.05	1.1
8th	.325	.5	.6	.8	1	1.5
9th	.35	.5	.7	1.		1.5
10th	.4	.5	.75	1.		1.6

It will be noticed that the spaces in the upper and middle part of the series are much narrower than in the lower part and are narrowest in the middle part.

In the Full Time Foetus the measurement of the/

the Intercostal Spaces gave : -

RIB.	HEAD.	NECK.	TUB.	ANGLE.	I.	2.	END OF BONY RIB.
1st	.1	.35	.35	.3	.3	.2	.2
2nd	.2	.35	.3	.35	.35	.2	.2
3rd	.2	.35	.3	.25	.25	.15	.15
4th	.2	.25	.3	.35	.2	.15	.15
5th	.2	.35	.4	.4	.3	.15	.2
6th	.2	.3	.3	.3	.25	.25	.3
7th	.2	.25	.35	.3	.35	.3	.4
8th	.2	.25	.3	.35	.4	.4	.45
9th	.35	.4	.35	.35	.4	.5	.6
10th	.25	.35	.5	.45	.4	.6	.6

As in the case of the Orang, the crowding together of the upper ribs as shown by the measurement of the upper spaces, is well shown in this series of measurements.

In/

The above photograph is that of a 6 months Anencephalic Foetus. There was only one Fallopian tube and one ovary found on the Right side in this specimen. The supra-renal capsule on the Left side was undeveloped.

In the Six Months' Foetus, the measurement of the spaces gives : -

RIB.	HEAD.	NECK.	TUB.	ANGLE.	I.	2.	END of BONY RIB.
1st	.2	.2	.2	.25	.25	.2	.4
2nd	.25	.25	.3	.35	.3	.25	.4
3rd	.3	.25	.25	.3	.2	.2	.25
4th	.3	.25	.25	.3	.2	.2	.25
5th	.3	.3	.3	.35	.25	.3	.3
6th	.2	.3	.3	.35	.25	.3	.35
7th	.25	.3	.3	.4	.3	.3	.35
8th	.25	.35	.35	.4	.35	.35	.3
9th	.25	.45	.45	.5	.35	.4	.4
10th	.3	.5	.5	.4	.35	.4	.4

The crowding together of the upper ribs and thus the narrowing of the intercostal spaces, is again here made evident.

In/

In the Youngest Foetus the measurements are : -

RIB.	HEAD.	NECK.	TUB.	ANGLE.	1.	2.	3.	END OF BONY RIB.
1st	.1	.1	.1		.2	.3		.35
2nd	.2	.2	.2	.15	.2	.25	.25	.3
3rd	.2	.2	.2	.15	.2	.2	.2	.2
4th	.2	.2	.2	.15	.2	.2	.2	.2
5th	.2	.2	.2	.15	.15	.15	.15	.2
6th	.2	.2	.2	.15	.1	.1	.15	.15
7th	.2	.2	.2	.25	.2	.15	.25	.3
8th	.25	.25	.25	.2	.3	.3	.3	.35
9th	.25	.25		.2	.3	.3	.35	.4
10th	.25	.25		.3			.4	.45

As we have seen, there is more of the circle, of which the first part of the rib is an arc - i.e. from the head to the angle - used up in forming this arc, in the case of the adult Man, than in the Monkey, and that there is less and less used as we go down in the scale to the youngest foetus.

It then occurred to me to enquire whether the ratio of the length of rib from head to angle to that of the rest of the rib from the angle to the end of the Bony Rib, was not increased in going up the scale from the youngest foetus up to Monkey and then on to Adult Man.

In fact, that as we had an increasing amount of arc used up in forming the first part of the ribs, from the head to the angle, whether we had not a corresponding increase of the above mentioned ratio as we ascended the scale from the Youngest Foetus up to the Adult Man.

The following Tables exhibit this ratio in full, and it will be seen that the ratio decreases as we go down the scale from Adult Man to Youngest Foetus.

In/

In an Adult Man the measurements gave : -

	LENGTH of RIB from HEAD to ANGLE.	LENGTH of RIB from ANGLE to END of BONY RIB.
1.	$1\frac{3}{8}$ inches.	$3\frac{1}{2}$ inches.
2.	$1\frac{5}{8}$	$6\frac{1}{2}$
3.	$1\frac{7}{8}$	$8\frac{1}{2}$
4.	$2\frac{1}{2}$	$9\frac{1}{4}$
5.	$2\frac{3}{4}$	$9\frac{3}{8}$
6.	$3\frac{1}{4}$	$9\frac{5}{8}$
7.	$3\frac{1}{2}$	10
8.	$3\frac{3}{4}$	$9\frac{1}{4}$
9.	$3\frac{3}{4}$	$8\frac{5}{8}$
10.	$3\frac{1}{2}$	$7\frac{1}{2}$
11.	$3\frac{1}{4}$	$5\frac{3}{4}$

The above measurements are given in inches. Account is not taken of the twelfth rib, because the 12th ribs of the Monkey and Foetuses measured were rudimentary.

For comparison, I shall now give the corresponding measurements in the Monkey and Foetuses.

In/

IN THE ORANG.

	HEAD to ANGLE.	ANGLE to END of BONY RIB.
1.	$\frac{3}{8}$ Inches.	$1\frac{1}{2}$ Inches.
2.	9/16	$2\frac{3}{8}$
3.	$\frac{5}{8}$	$2\frac{7}{8}$
4.	$\frac{3}{4}$	$3\frac{1}{4}$
5.	$\frac{7}{8}$	$3\frac{1}{4}$
6.	15/16	$3\frac{1}{8}$
7.	1	3
8.	$1\frac{1}{16}$	3
9.	$\frac{7}{8}$	$2\frac{5}{8}$
10.	$\frac{3}{4}$	$2\frac{1}{2}$
11.	$\frac{5}{8}$	$1\frac{3}{8}$

Now by taking the ratio in the case of each rib separately, of the figure in the first column to that in the 2nd column, and comparing the ratio rib for rib, with the Adult Man, we shall see that the ratio is greater in the Adult Man than the Monkey. We shall also find that the ratio is greater in Monkey than Full Time Foetus, and in the latter than in the 6th Month Foetus, and so on.

Thus in the case of the 1st Rib of Adult Man/

Man we have : -

$$\frac{1\frac{3}{8}}{3\frac{1}{2}} = \frac{11}{28}$$

In the case of the Monkey : - $\frac{\frac{3}{8}}{1\frac{1}{2}} = \frac{3}{12} = \frac{1}{4}$

Now $\frac{11}{28}$ and $\frac{1}{4}$ when brought to a common denominator give - $\frac{11}{28}$ and $\frac{7}{28}$, thus showing that the ratio is greater in the case of the Adult Man. Adopting this plan for all the ribs, we find that the numbers representing the ratios are respectively:

	MAN	MONKEY.
1st Rib	11	7
2nd	38	36
3rd	345	340
4th	130	111
5th	572	525
6th	260	225
7th	21	20
8th	720	629
9th	30	23
10th	70	45
11th	143	115

Monkey/

THE MEASUREMENTS in the CASE of the FOETUSES gave in CENTIMETRES : -

	FULL TIME		6 MONTHS'		YOUNGEST	
	Head to Angle	Onwards.	Head to Angle	Onwards to end	HEAD to Angle	Onwards.
1.	6 cm.	2.5cm	.55	2.35	.15	.8
2.	1.2	4.5	1	4.2	.4	2.3
3.	1.25	5.8	1.05	5.1	.5	3
4.	1.35	6	1.15	5.3	.6	3.2
5.	1.5	6.4	1.3	5.7	.7	3.3
6.	1.65	6.8	1.35	5.8	.85	3.7
7.	1.75	6.1	1.4	5.8	.9	3.8
8.	1.8	5.7	1.5	4.9	.95	3.5
9.	1.7	5.15	1.3	4.3	.7	3
10.	1.2	4.1	.9	3.5	.5	2.8
11.	1	3.1	.7	2.8	.4	2.4

Comparing these ratios with each other and with those of the Monkey, we get for the numbers showing the comparison : -

FULL/

	MONKEY	FULL TIME FOETUS.
1st Rib	25	24
2nd	135	76
3rd	580	575
4th	120	117
5th	448	390
6th	408	330
7th	122	105
8th	323	288
9th	515	510
10th	123	120
11th	155	110

Similarly comparing Full Time Foetus with 6 Months' Foetus we obtain :-

FULL /

	FULL TIME FOETUS.	SIX MONTHS' FOETUS.
1st Rib	282	275
2nd	84	75
3rd	850	812
4th	954	920
5th	850	832
6th	3828	3672
7th	1015	854
8th	294	285
9th	1462	1339
10th	420	369
11th	40	31

	SIX MONTHS' FOETUS.	YOUNGEST FOETUS.
1st	176	141
2nd	115	84
3rd	42	34
4th	368	318
5th	429	399
6th	1998	1972
7th	266	261
8th	1050	935
9th	390	301
10th	252	175
11th	6	4

THE STERNUM.

We should, of course, be led to expect differences in the Sterna in the series we have been considering, after seeing the differences in the rest of the thorax.

It varies in the Human Adult much in size and shape and direction. It is said to be usually longer in men than in women. In regard to this latter matter Prof. Dwight (1) of Harvard has recently published an instructive anthropological study on the size of the articular surfaces of the long bones as characteristic of sex. He notes how the pelvis has long been recognised as a reliable guide to the sex of a skeleton, and we may add that Prof. Thomson has demonstrated that the essentially sexual characters of the pelvis are already as well defined during foetal life as in the Adult. Hyrtl laid great stress on the distinctions between the male and female sternum.

The manubrium of the sternum in women exceeds in length that of half the body, whilst in the male sternum the body is at least twice as long as the/

(1) American Journal of Anatomy. Vol. IV. No. I. Decr. 20th, 1904.

the manubrium. Dwight however found on measuring several large series of sternums about 40% of exceptions and concluded that probably the rule applied to well formed bodies, but not to a large proportion of those we meet with.

The gladiolus is, as a rule relatively shorter in women than in men. The length of the sternum is not by any means always proportionate to the size of the individual; it varies not only in length but in breadth & thickness. The direction of the bone is commonly at an angle of 20° to 25° to the perpendicular, but the direction of the manubrium is not the same as that of the gladiolus. This gives rise to the Sternal Angle (Angulus Ludovici) named after Louis of Paris.

	MANUBRIUM.	BODY.	XIPHISTERNUM.
Adult Man.	5.1 cm.	10.5 cm.	3.5 cm.
Monkey	1.7 cm.	3.3 cm.	2.55 cm.
Full Time Foetus.	1.4 cm.	2.6 cm.	1.3 cm.
Six Months' Foetus.	1.3 cm.	2.5 cm.	1.3 cm.
Youngest Foetus below six months.	1.15 cm.	2.1 cm.	.9 cm.

Thus, in Man, the Body is twice that of the Mannbrium in length, but under this in the case of/

of all the rest.

As showing the extent to which the sternum is tilted, I find that the measures of the Inlet & Outlet of the Thorax give respectively : -

	INLET.		OUTLET. opposite the 8th Rib.	
Adult Man.	Transv.	Ant. Post.	Transv.	Ant. Post.
Monkey	5.9 cm.	3.1 cm.	14.5 cm.	7 cm.
Full Time Foetus	4.6	1.8	6.8	4.9
Six Months' Foetus	3	1.3	6.4	3.8
Youngest Foetus	2	1.1	3.6	3.4

These numbers show that the ratio between the Transverse & Antero Posterior diameters is very much altered from that of the Adult Man, as we go down the scale from Adult Man to Youngest Foetus.

The volume of the chest, however, cannot furnish any special character. Its development is enormous in the three Anthropoid Apes.

The ratio is altered in great measure owing to the increase in the Curvature of the Dorsal spine in the Foetuses. They have no lumbar curve whilst the Monkey has one. (1)

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(1) Cunningham

T H O R A C I C   S P I N E .

The Thoracic Spine, composed of the 12 Thoracic Vertebrae, presents normally two curves, one with the convexity backwards, is always present; the other, the lateral one, usually with the convexity to the right, but occasionally to the left, is often so slight as to be scarcely perceptible. The Thoracic isthe least flexible region of the moveable part of the Vertebral Column, the antero-posterior movements being limited by the small amount of intervertebral substance, and the imbrication of the spines and laminae, the lateral movements by the approximation of the Ribs; a slight degree of rotation about a vertical axis is, however, permitted. It is probably due to the slight obliquity of the articular processes, that whenever exaggeration of the normal lateral curve of the spine occurs, as in Scoliosis or after empyema, a certain amount of rotation or torsion is invariably present. As a result of this torsion, these spines always point towards the concavity of the curve, while the bodies of the vertebrae are twisted outwards, and consequently the angles of the Ribs become more prominent on the convex side of the curve, and the rib cartilages on the concave side.

These/

These distortions of the chest modify very much the relations of the Thoracic Viscera to the surface of the body - the manner in which the spine projects into the Thoracic cavity, and forms as it were

?

NOTES ON THE SPINE.

The spine performs the following functions. It forms (1) a protection to the Spinal Cord.

(2) It acts as a scaffolding on which the larger vital cavities are built.

(3) It allows a pliancy to the body which is conformable to all the torsions which the body may undergo, but the pre-eminent and primary function is to

(4) So regulate the relative positions of the upper and lower portions of the body that the centre of Gravity may be brought back again to its proper position, consonant with the erect posture, after any shifting of the relative parts of the body.

The/

The measurement of the Thoracic Spine in the Monkeys and Foetuses gave : -

	ALONG THE HEADS OF THE RIBS.	ALONG FRONT SURFACE.
ORANG	10.6 cm.	10.1 cm.
FULL TIME FOETUS.	6.8	6.4
6 MONTHS' FOETUS	6.3	5.9
YOUNGEST FOETUS.	3.9	3.5

The Depths of the Thorax from the angle to the level of the Front of the Vertebral Column gave : -

Opposite	ORANG	FULL TIME FOETUS	6 MONTHS' FOETUS	YOUNGEST FOETUS.
1st Rib	1.1cm.	.8	.3	.2
2nd	1.75	1.05	.75	.4
3rd	2.1	1.1	.8	.5
4th	2.15	1.2	.9	.55
5th	2.2	1.3	1.	.6
6th	2.25	1.4	1.1	.68
7th	2.4	1.5	1.15	.85
8th	2.55	1.55	1.2	.9
9th	2.8	1.3	1.1	.8
10th	2.75	1.2	1.	.65
11th	2.7	1.1	.9	.6

Transverse/

TRANSVERSE DIAMETER OF THORAX.

In the Human Adult, the Transverse diameter is much greater than the antero-posterior and the maximum of the Transverse Diameter being opposite the 8th or 9th Rib (Cunningham) and is largely owing to the forward projection of the Thoracic part of the Vertebral Column into the Thoracic cavity.

The width of the Thorax at different levels comes out as follows: -

Opposite	ORANG	FULL TIME FOETUS	6 MONTHS' FOETUS	YOUNGEST FOETUS.
1st Rib	6.1cm.	4.4	3.6	.2
2nd	7.5	5.6	4.7	2.9
3rd	9	6.2	5.1	3.3
4th	10.4	6.4	5.3	3.6
5th	11.8	6.5	5.6	4
6th	12.8	6.7	5.8	4.1
7th	13.7	7.2	5.9	3.7
8th	14.5	7.4	6	3.5
9th	15	7.2	5.8	3
10th	15.8	6.6	5.6	2.3
11th	16	6.2	5.1	1.5

DEPTHS OF THORAX.(2)

Comparing these last measurements with the

Total/

FULL TIME FOETUS. Inlet of the Thorax shown. Also width of the outlet well seen, and the comparatively large Antero-Posterior diameter of the Thorax.

Total Depth of the chest at the same levels we get: -

Opposite	ORANG	FULL TIME FOETUS	6 MONTHS' FOETUS	YOUNGEST FOETUS
1st Rib	3.9cm.	2.2	1.5	.7
2nd	5.4	3.7	2.5	1.8
3rd	6.1	4.6	2.8	2.3
4th	7.1	4.9	3.6	2.6
5th	7.9	5.4	4.1	2.8
6th	8.5	5.8	4.7	2.9
7th	8.7	5.9	5.3	2.8
8th	9	5.8	5.4	2.6

It is again interesting to compare the measurement of the Depth of the Chest from the Sternum to the front of the Vertebral Column. We can then see that in the monkey and Foetuses, the development backwards from the Vertebral Column to the Angles is small compared to what it is in Adult Man.

Distances of the Front of the Vertebral Column from the Front Chest Wall.

Opposite	MONKEY	FULL TIME FOETUS	6 MONTHS' FOETUS	YOUNGEST FOETUS.
1	3.3	1.2	.8	.3
2	4.3	2.8	1.5	1.2
3	4.5	3.8	1.9	1.5
4	5.1	4.5	2.2	1.7
5	5.4	5	2.3	1.9
6	5.8	4.2	3	2.2
7	6.1	4.3	3.2	1.8

COSTAL/

COSTAL CARTILAGES.

In the Adult Man the Costal Cartilages increase in length from the 1st to the 7th Rib, below which they become shorter. The first inclines obliquely downwards and inwards to unite with the upper angles of the manubrium. The 2nd lies more or less horizontally. The 3rd to the 7th gradually become more and more curved inclining downwards from the extremities of their respective ribs, and then turning upwards to reach the sternum (Cunningham)

In the Monkey, the 1st two cartilages incline downwards to the sternum, whilst the rest slope up. The actual angles they make with the sternum are:-

1st 25° down
2nd 11° "
3rd 7° up
4th 22½° "
5th 32° "
6th 33° "

The 7th does not reach the sternum.

HEIGHT TO WHICH THE DIAPHRAGM RISES.

In the Orang I found that the Diaphragm rose -

ON RIGHT	ON LEFT.
Upper border body of 6th Dorsal Vertebra	Lower border of body of 6th Dorsal Ver.

The/

The central tendon of the Diaphragm is at the level of the disc between the 7th and 8th Dorsal Vertebrae or the upper border of the body of the 8th Dorsal Vertebrae.

Symington says that in the young child the central tendon of the Diaphragm is nearly horizontal and at the level of the Disc between the 8th and 9th Dorsal Vertebrae. It is a little lower in the Adult Man.

In Branne's Atlas Plate I. there is a drawing of a mesial section of an adult male subject, in whom it is in front of the disc between the 9th and 10th Dorsal Vertebrae.

In Plate II. it is opposite the Disc between the 8th and 9th Dorsal Vertebrae.

In the foetus the Diaphragm rises to the height of the Disc between the 7th and 8th D.V. on the Left, and to the lower border of the body of the 7th Dorsal Vertebra on the Right.

The diaphragm when measured after death, may be taken to be in a condition of expiration and these measurements therefore, are those of the Diaphragm during expiration.

To compare the backward development towards its angles of the Orang, with Man, the following figures are of interest:-

Amount/

	AMOUNT of RIB BEHIND LEVEL of the FRONT of the VERTEBRAL COLUMN.	AMOUNT of BONY RIB ONWARD.	LENGTH of CARTILAGE.
1st Rib.	$1\frac{1}{4}$ in.	$1\frac{1}{8}$ in.	3/16 in.
2nd "	2	$1\frac{1}{16}$	$\frac{7}{8}$
3rd "	$2\frac{1}{4}$	$1\frac{5}{8}$	1
4th "	$2\frac{1}{2}$	2	$1\frac{3}{8}$
5th "	$2\frac{5}{8}$	2	$1\frac{3}{4}$
6th "	$2\frac{3}{4}$	$1\frac{3}{4}$	$2\frac{5}{8}$
7th "	3	$1\frac{3}{8}$	$2\frac{5}{8}$
8th "	$3\frac{3}{8}$	$\frac{7}{8}$	$2\frac{1}{8}$
9th "	$3\frac{3}{8}$	$\frac{3}{8}$	$1\frac{1}{8}$
10th "	$2\frac{5}{8}$		$\frac{1}{4}$
11th "			

The /

The Inclination of the Ribs to the Vertebral Column in the Orang were measured at the Three points -

	TUBERCLE	ANGLE &	ONWARDS.
1st	85°	77°	4° (upwards from spine)
2nd	83°	77°	98°
3rd	84°	83°	88°
4th	85°	77°	86°
5th	83°	85°	87°
6th	72°	78°	80°
7th	76°	78°	75°
8th	69°	77°	73°
9th	60° upwards fr.spine	67°	70°
10th	52°	6°	64°
11th	43° upwards	45°	48°

Where upwards is written, it means that the angle was measured from the top of the rib to the spine, in the other cases from the bottom of the rib to the spine.

We see from the measurements and comparisons that have been made, that the shape of the Chest of the Monkey, occupies a place intermediate between that of the human foetus and the Adult human being, and/

and that it lies much nearer the Foetus than the Adult. From a consideration of the ordinary method of progression in Man and Monkey, and the position of the Human Foetus in utero, one might quite readily have expected the results which have been seen to exist.

The whole subject of shape turns on the Erect posture adopted by Man.

Topinard (1) remarks - "Although having attained so lofty an eminence, man must have had a very low origin, in no way differing from that of the first and most simple organic corpuscles. What he is now in the womb, he would have been permanently on making his appearance in the animal series."

We have seen from our measurements that in the womb is simply what one would expect from a consideration of the Mechanics of his position there.

There is, however, nothing to go on in regard to his derivation from a previously existing form, if that be admitted.

In regard to this matter Topinard(2) again remarks - "The derivation of Man from some previously existing/

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(1) Anthropology Part II. Chap.I.p.533.

(2) " Part III. Chap I. p.530.

existing form being admitted, the question is what this form may have been. Lamarck believed it to be a chimpanzee. We have seen that each of the three great anthropoids approaches more or less to man in certain characters, but not one possesses them all. So in the inferior races, no one race, not even the Bosjesnian, is specially marked out as descending from an anthropoid - they are only made to approach more or less by such or such a character.

The precursor of Man, then, is only analogous to the Anthropoids. The human type is an improvement upon the general type of their family;, but not of one of their known species in particular.

And again : - In a word, the anthropoid ape is a biped, but he possesses an arrangement of the feet which allows him to walk, upon the branches of trees. He is bimanous, but he has the assistance of his hands in walking, as we ourselves should have, if, with longer arms, we wished to imitate him. His attitude in progression is more nearly the vertical than the horizontal, and is sometimes that of Man and sometimes that of quadrupeds.

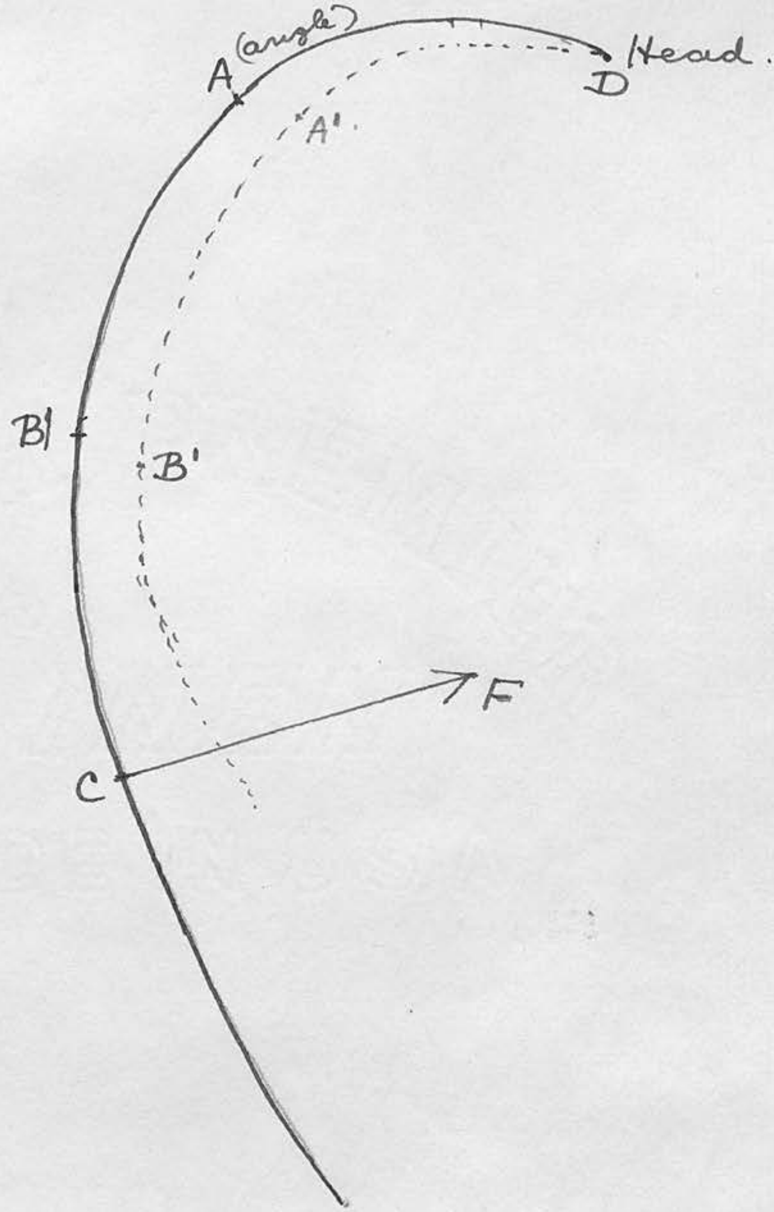


fig I.

DABC is a rib acted on by a force F applied at C as in the figure.

NOTES ON FRACTURE OF THE RIBS DUE TO INDIRECT VIOLENCE.

The fracture of the ribs which takes place as a result of indirect violence e.g. by a crush in a crowd usually occurs a little distance in front of the angle.

It is frequently said that it breaks like an overstretched bow, but this is not the case.

It would break like a bow if the curvature were the same from the head to the end of the bony rib providing that the rib were uniform in structure between these points.

We have shown in the measurements that have been given that in all the ribs except the first and last, there are more than two changes of curvature. This alone is sufficient to disprove the saying that a rib breaks like an overstrung bow.

Moreover it is a matter of common experience that the rib breaks just in front of the angle.

If the rib broke like a bow, it would break somewhere about the middle, i.e. a long way in front of the angle.

FRACTURE OF THE RIBS.

Consider a rib as in the figure I acted on by a/

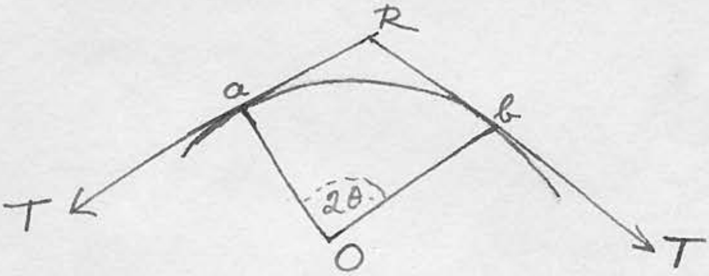


fig 2.

T & T are the two tensions (equal) which keep the uniform arc in the shape it possesses in the fig. They act in the direction of the tangents to the curve at a & b respectively.
a O & b O are the normals to the curve at a & b respectively.
The angle a O b = 2θ

a force F, at c. This is at right angles to the curve at C.

This force bends the rib into the portion A^1B^1 say.

Now consider the equilibrium of the part A^1B^1.

The curvature of the rib in the figure is supposed to change at A and B. (as we have shown is always the case).

Now take a very small arc. ab, of the portion A^1B^1. fig. 2.

Now ab, is kept in equilibrium by the two tensions T and T which act along the tangents at A and B to the arc. and are produced by the force acting at C.

Let the normals aO, bO to the small arc. ab, meet at O, the centre of curvature of the section.

Then if 2θ be the angle aOb, and if P be the pressure per unit of area over the arc. ab. we have for the total pressure on the arc. ab. (p × arc. ab.)

Now resolving the two forces T. along RO and perpendicular to RO. we see that along RO. we have 2 T cos bRO i.e. 2 T sin O. and perpendicular to RO we have $T \cos \theta$ pulling in the one direction, and

$T \cos \theta$ pulling in the opposite direction. fig. 3

These two balance each other. We are, therefore, left with the force. $2 T \sin \theta$ acting in the direction /

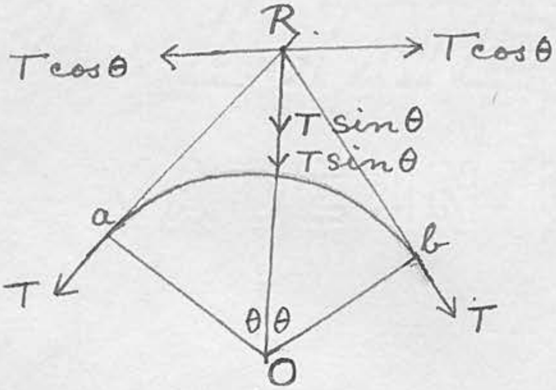


fig. 3.

In this figure the two forces T & T acting at a & b respectively have each been resolved into their two components respectively, along the direction RO & perpendicular to this direction.

Thus the force T acting in the direction Ra has been resolved into T sin θ, along RO & T cos θ acting at right angles to RO, & similarly for the force T acting at b along the direction Rb.

direction RO.

$\therefore$ the resultant pressure from within the arc outwards to balance this force (since it does just balance it) is equal to 2 T sin θ.

We have seen however, that this force is equal to (p×arc. ab).

$\therefore$ p×arc. ab. = 2 T sin θ. (i) i.e.

Now since the arc. ab. is very small

$\therefore$ so is the angle θ, and

$\therefore$ we may put sin. θ = θ.

Again, arc ab ÷ radius of circle of ~~ab,~~ which ab is part (= R.)

i.e. $\frac{\text{arc ab}}{R} = 2\theta$

or arc. ab = 2 Rθ.

$\therefore$ 2 T θ = p.2.Rθ. from (i) since sin θ = θ, or

$$p = \frac{2\ T}{R}$$

Now applying this reasoning to all the small arcs. of which AB fig. I is composed, we see that the resultant of all the pressures, along the arc AB, will, (if AB be uniform) act through the middle point of AB in the direction of a line passing through the centre of curvature of AB.

Similarly, the result of the pressure on the first arc. from the Head to the Angle A, will act through /

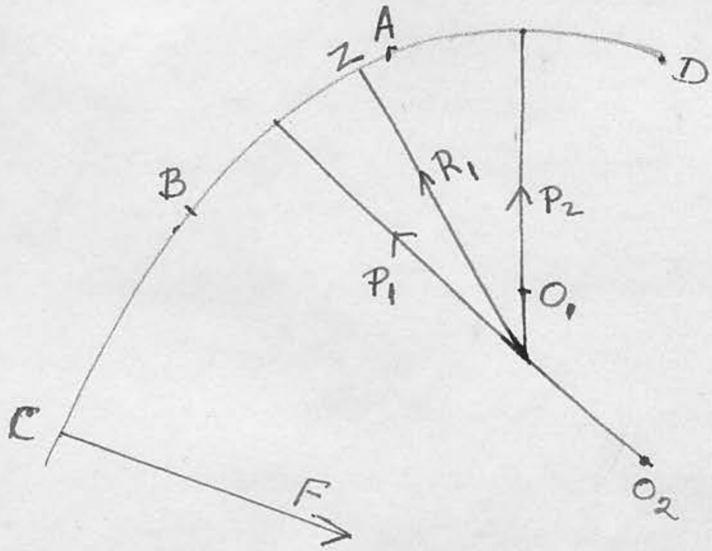


fig. 4.

P_1 & P_2 are the resultant pressures on the arcs AB & AD respectively, & they pass through the centres of curvature of AB (O_2) & AD (O_1) respectively.
The resultant pressure of P_1 & P_2 i.e. R_1 passes through the point Z.

through the centre of the arc. DA. and will pass through the centre of curvature of the arc AD. fig. 4.

If these two lines of direction meet in O, then the resultant R_1 of P_1 and P_2 will pass in same direction OZ and will pass to one or other side of A according as P_1 or P_2 is the greater.

If the rib were uniform in material throughout, then, since AB is larger than AD,

∴ the total pressure over AB would be larger than that throughout AD, and the resultant pressure would pass as in the figure.

This point Z is therefore the point at which the rib would break.

As a matter of fact, taking into consideration the density of the rib, the force P_1, is greater than that of P_2.

This is a priori evident, as the rib obviously contains more mass per unit of volume, i.e. it is denser from the head to a point on the other side of the angle A, equal in length to that from the head to A, than it is elsewhere.

So we see that the point through which the resultant force will act, lies on the side of the angle towards B, and depends entirely on the size of the two resultant pressures P_1 and P_2.

When the stress is greater than the tenacity of the rib can stand, it will break at the point, through /

through which this resultant force acts.

If the rib broke as a bow (uniform breaks) it would give way at the point which is midway between D and B.

The fact that the rib is not solid makes it more fitted to resist pressure. Moreover it combines lightness and power of resistance to all bending or buckling stresses, just as large hollow cylinders, such as are used in the structure of the Forth Bridge, are more efficient than solid cylinders of the same size.

In experimenting in this way, one can use the above theorem to all parts of the rib, but it must be applied to small parts at a time, and the different results then dealt with. Because no rib lies entirely in one"vertical plane" as has been previously seen, it is sometimes wrongly stated that the rib has a twist or torsion. This is not so. The apparent twist or torsion is due to the rib having several curvatures in the vertical plane, which at first sight appear to give it the appearance of having been twisted.

None of the ribs are, of course, fixed rigidly, so that their liability to fracture is thus lessened. But besides this they have fairly great flexural rigidity, that is to say, suppose we take any portion AB of a rib, then,

the total stress couple which acts across any /

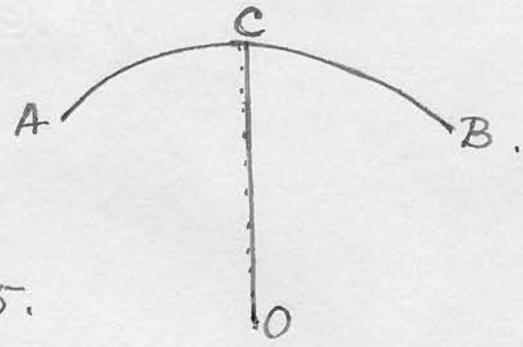


fig. 5.

AB is a portion of a Rib whose flexural rigidity is under consideration. r CO is its radius of curvature.

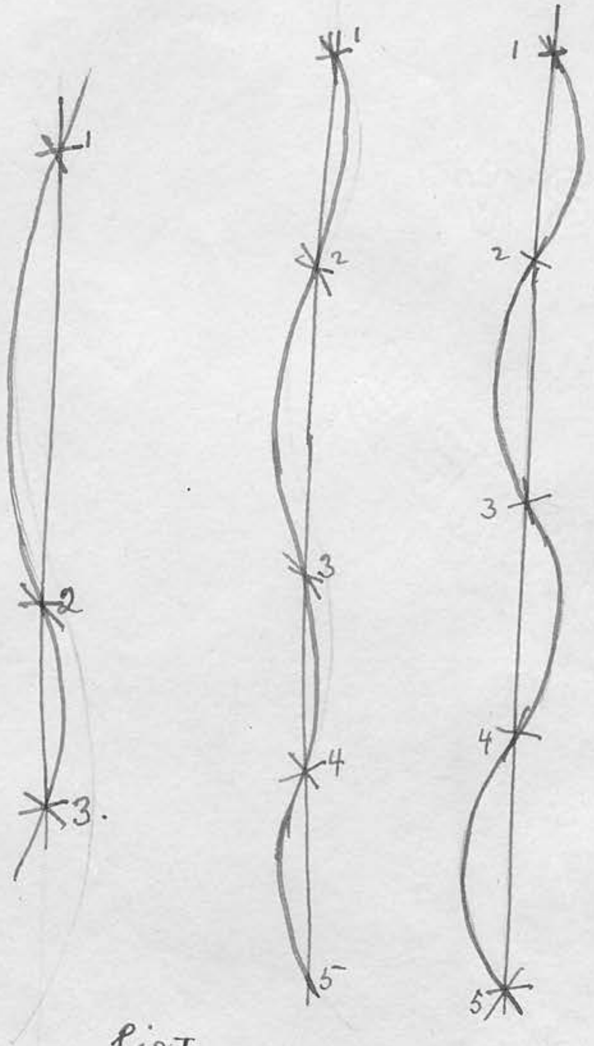


fig I

Foetus. Monkey. Adult Man

fig. Showing the curve of the Adult human spine to be cut five times by it own axis, whilst in the foetus, it is cut but three times. In the Orang it is cut five times, but the curves are not nearly so well developed as in the Adult Man.

any section of AB, multplied by the radius of curvature of AB, is a comparatively large quantity.

Since each rib consists of a curved and flattened bar of bone, the interior of which is loose and cancellous, whilst the investing envelope is compact, the inner table is much the stronger attaining its maximum opposite the angle in front and behind which it becomes gradually reduced. The outer table much thinner is stoutest opposite the angle on the posterior surface of the tubercle, and neck, and forms but a thin layer. It is most compact in the region of the head and towards the anterior extremity. (Cunningham).

In order to have great flexural rigidity, the moment of inertia of a section must be as great as possible, consistent with the other conditions: e.g. a hollow cylinder will resist bending stresses much more effectively than a solid cylinder of the same mass per unit length, and because of its comparative lightness, will also be more efficient than a solid cylinder of the same size.

Moment/

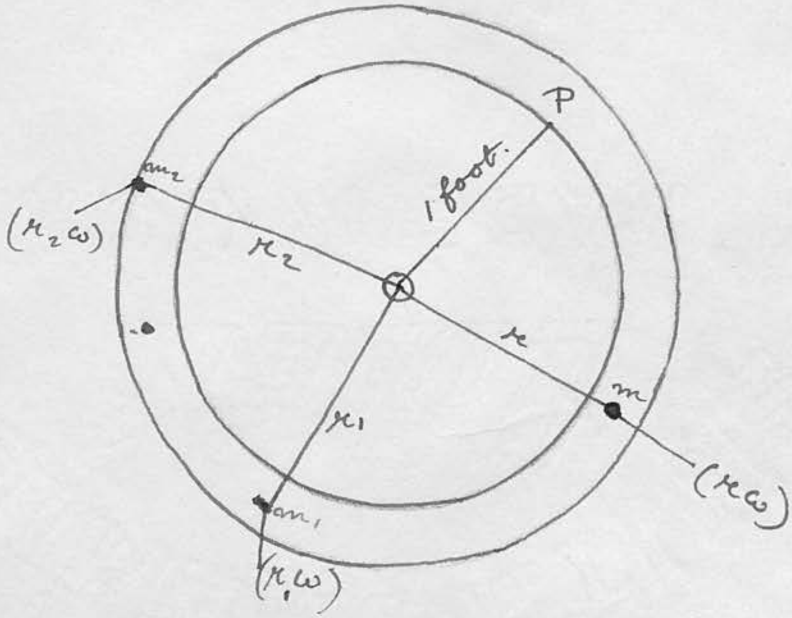
MOMENT OF INERTIA.

The moment of Inertia of a body depends on the mass (i.e. quantity of matter in the body) and the distribution of that mass relatively to a given axis.

Thus, take the case of a fly wheel of a stationery engine. The wheel as a whole is rotating about a fixed axis. Every part of a wheel has a definite speed, which is proportional to its distance from the axis. Let a be the speed of any point P at unit distance (one foot)from the axis (through the centre O at right angles to the plane of the paper), or as it is usually expressed - Let a be the angular speed. The ra will be the speed of the part distant r from the axis. The wheel may be regarded as built up of a great many small elements. Then if m, be the mass of one of these elements at distance r_1 its Kinetic energy is : -

$$\tfrac{1}{2}m_1 (r_1\omega)^2 = \tfrac{1}{2}m_1 r_1{}^2\omega^2$$

The quantity (omega) belongs to the wheel and has the same value whatever part be considered. Thus, the Kinetic Energy of the element m_2 whose distance is r_2 is $\frac{1}{2} m_2 r_2{}^2\omega^2$ and so on for all the elements which build up the wheel. The Kinetic energy of the whole/



To illustrate Moment of Inertia of a Fly wheel. The axis of Rotation is supposed to be through O at right angles to the plane of the paper.

m, m_1 & m_2 are the masses of different small elements at distances r, r_1 & r_2 respectively from the axis through O & ω is the angular speed common to all of them.

whole wheel is the sum of the Kinetic energies of all the constituent elements or : -

Kinetic Energy

$$= \tfrac{1}{2}\omega^2(m_1r_1^2+m_2r_2^2+\ldots+m_nr_n^2+1)$$

The quantity within the brackets measures what is called the Moment of Inertia of the body about the given axis. (Knott Physics. An elementary Text Book for University Classes, Edinburgh 1897.)

The farther removed the substance of a body happens to be therefore, from its axis of rotation, the greater is the amount of its Inertia, and the greater will be its Kinetic Energy for a given rate of rotation.

NOTES ON SPINAL CURVATURE.

SPINAL COLUMN.

The Dorsal and Sacral curves are the only curves of the spine in the human foetus. They make their appearance very early in foetal life. They are due to the conformation of the Vertebral Bodies.(1)(2)

The Cervical and lumbar curves are secondary or compensatory curves, necessary to the upright posture, only developed after birth in the human being, and dependent mainly on the shape of the intervertebral discs.

In the upper dorsal region, there is also very frequently a slight degree of lateral curvature, the convexity of which is directed towards the right side.

The Monkey differs from the foetus in possessing all the curves that the Adult Man possesses.

It used to be thought that it possessed no lumbar curve, and that this was one of the chief points that distinguished anthropoid apes from Man. It has been shown, however, to be possessed of a lumbar curve.(3)

In/

(1) Quain Osteology.

(2) Keith Embryology.

(3) D.J.Cunningham. The Lumbar Curve in Man & Apes. Dublin 1886 and Proc.Roy.Soc.1889.

In Europeans the bodies of the lumbar vertebrae are collectively deeper in front than behind, to agree with the curvature of this part of the column; but at the same time there are certain differences to be noted in individual segments. For example, in the third, 4th and 5th the anterior depth is greater than the posterior, in the 2nd the anterior and posterior diameter are nearly equal, whilst in the first lumbar the posterior is deeper than the anterior.

In the dark races of Man (Australian, Negro, etc.) the depth of the five lumbar bodies together, is greater behind than in front, and the fifth is the only one, in which the anterior depth notably exceeds the posterior. It does not appear probable however, that this conformation of the Vertebral bodies is accompanied by a less marked degree of lumbar curvature, since the latter is determined mainly by the intervertebral discs.(1)

(1)N.Turner. Journal Anat.xx. and Challenger Reports Zoology xvi.

& D.J.Cunningham loc cet.

CURVES of the SPINE.

The column in profile presents 4 curves directed alternately backwards and forwards, - forwards in the Cervical and lumbar regions; backwards in the dorsal and sacral.

It is cut by its own axis in 5 points as shown in the figure. This is true also of the Orang. In the human foetus it is cut three times only by its own axis.

"There is a series of lateral curvatures in the dorsal region convex to the Right; Cervical and Lumbar convex to the Left. Sacro-Coccygeal to the Right. If the lateral and antero-posterior curves are connected together they resolve themselves into a corkscrew-like curve, not the curve of a thread running regularly round a cylinder, but arranged so as to increase or diminish in their course. In disease these curves increase, dorsal to the Right cervical to the Left, lumbar to the Left and sacro-coccygeal to the Right." (1)

It is of interest here to notice the curvatures of the surface of the articular facets of the Vertebral column and also the spiral arrangement of the /

(1) Goodsir Anat. Memoirs.

the trunk muscles (Obliqui, serrati etc. which are arranged in corkscrew- like spirals around the body. This was first pointed out by Weber.)

These curvatures of the bones and the spiral arrangements of the muscles allow the human body to be thrown into all sorts of peculiar twisted attitudes.

From these twisted attitudes as well as from the biped mode of progression in man, it is quite evident that his centre of gravity must be constantly changing. It is therefore necessary to have some arrangement for constantly bringing it back to its normal position.

The naturally normal position of the centre of gravity and the perfect symmetry of the human body are co-existent and relatively dependent. Around this centre of gravity are exactly reared and correctly balanced the elements of the frame in a manner best suited to the alternating motions in walking and running, and it is to the effort of retaining this centre in its proper and most suitable position that the Spine is specially devoted.

FUNCTIONS /

FUNCTIONS of the SPINE.

The Spine serves

(1) as a protection to the Spinal Cord.

(2) as a scaffolding on which the larger vital cavities are built.

(3) It permits of torsion of the body.

(4) Regulates the position of the Centre of Gravity.

Loss of shape or deformity arises either

(1) from faults in the evenness and balance of the musculo-nervous powers of the body, on which the stability of the skeleton depends, e.g. Paralysis or Spasm;

or (2) From faults in the construction of the skeleton itself, e.g. shortening of the leg in hip disease, in which case the attempt of the body to rear itself on an uneven base brings about the deformity.

In the natural state of the spine there are 4 curves which are so arranged as to balance the body evenly in the erect posture and to give it most elasticity.

Whenever anything unnatural in the surroundings arises then a new series of curves begins to form /

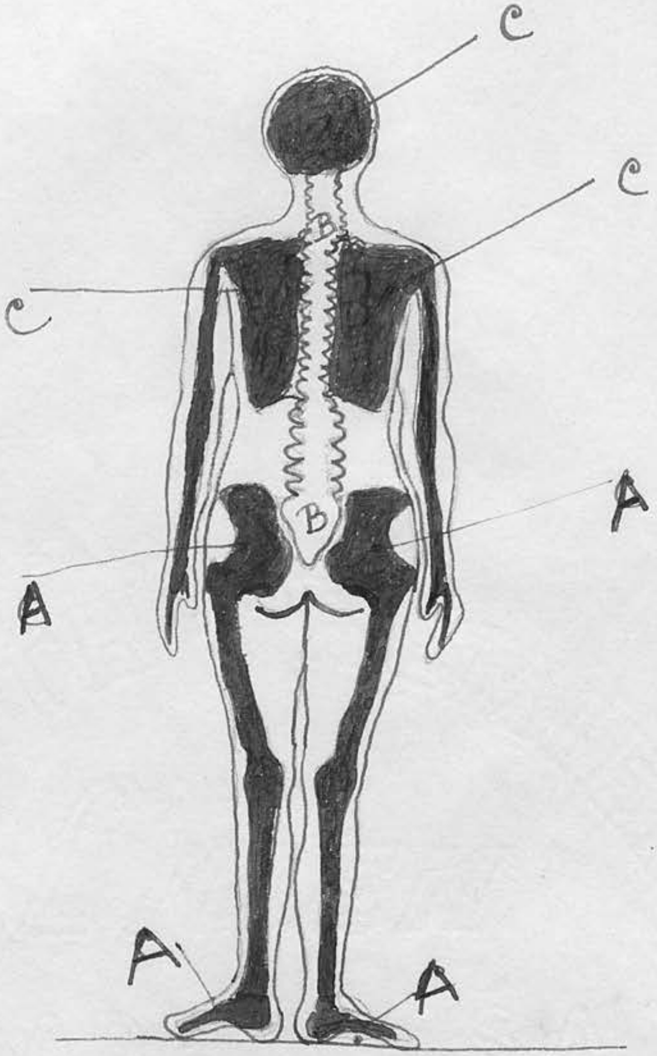


Diagram to show the relation of the spine (B) to its arches (A) below & the weight it has to support (C) above.

pp. 4

form, and these being unnatural are recognised as deformities.

The spine has a tendancy to assume definite curves according to its surroundings, this latter term being applied to the base on which it rests and the burden it has to bear.

For example when the right arm is more muscular then the left there is constantly found in the spine, in the dorsal region, a slight curve convex to the right.

The spine may be considered to be dependent for its erectness on three arches viz. the arch so formed by the leg - thigh - and hip-bones, which have the sacrum for a keystone, and the two arches of the feet.

Moreover it is in relation to the three important cavities viz. the Thorax, Abdomen and Spinal Canal, and the shape of each of these is governed by and consequent on the integrity of its shape.

By Spinal Curvature is meant an unnatural curvature of the Spine. It is usually classified according to the region in which it occurs, e.g. cervical, lumbar etc. or according to direction e.g. lateral etc.

A classification based on the mechanical origin /

origin of spinal curvature would simplify matters by dividing the curvatures into those which are due to the Spine itself and those that are due to the three arches on which the spine rests or due to the burden which the spine supports.

Full Time Foetus. showing the curve of the spine, the large antero-posterior development of the thorax & the large outlet.

Six months' anencephalic Foetus
In this foetus there was no
development of the Fallopian
Tube & Ovary on the Left Side.

Full Time Foetus showing
the horizontally directed
upper ribs.

View of the Inlet of the Thorax
of a Full Time Foetus.

Side View of the Full Time Foetus. Curve of the Spine well seen. the shallow fossae for the Erector Spinae muscles & the horizontal direction of the Ribs.