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THE FEMALE PELVIS.

BY

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In the numbers of the *Edinburgh Medical Journal* for August and September 1855, I published a paper entitled, "On the os sacrum considered as forming part of the vault of the pelvis, and on its function in the development of the lateral expansion of that cavity." Founding on the principles established in this paper, and which have since then received ample confirmation by authors in this and other countries,[1] I engaged in the study of the deformities of the pelvis. Some of the results of the investigation, having reference to the oblique-ovate pelvis, formed the termination of the paper just named. My natural progress to the rachitic and malacosteon deformities of this part was interrupted by the paper of M. Meyer on this subject coming under my notice. In this memoir most of my views were more than anticipated, and I satisfied myself with embodying some of the results of his investigations in a paper entitled, "Notes on the formation of the rickety and malacosteon pelvis, chiefly after the researches of M. Meyer of Zurich." This appeared in the number of the *Edinburgh Medical Journal* for April 1856.

Considerable discussion has taken place regarding some of the questions raised in these papers. But the views expressed regarding the mechanical conditions of the sacrum have been so generally accepted, that I will not return to their support, but will now assume them as established. The application of these views to the explanation of the development of the pelvis in healthy and morbid states, has been in some quarters received with hesitation, or altogether opposed.[2] Much of this, I believe, has been owing to the brevity and imperfection of my descriptions and arguments; and

[1] See Meyer, *Lehrbuch der Physiologischen Anatomie;* Giraud-Teulon, *Mécanique Animale;* Hubert and Valerius, *Mémoires de l'Académie Royale de Médicine de Belgique*, Tome IV.; and *Gazette Médicale de Paris*, p. 722, 1856.

[2] See Moore on the Sacrum, *British and Foreign Medico-Chirurgical Review*, vol. xx., 1857; also Wood on a specimen of pelvis oblique ovata, *Transactions of the Pathological Society of London*, vol. vii., p. 292.

having now reconsidered the matter with the aid of the criticisms alluded to, I am desirous to confirm my former statements by an exposition of more matured investigation of the subject. I shall hold it proved that the sacrum is neither a wedge nor the key-stone of an arch, and confine myself to the development of the lateral expansion of the pelvis. I shall call to my assistance the anatomy of deformed pelves, believing that they may be regarded, for the purposes of this inquiry, as experiments performed by nature to aid in the discovery of the parts played in the development of this osseous circle by its component bones and joints.

It is necessary to premise that certain average conditions and measurements of the pelvis are assumed as the natural ones; but in no case will it be found that any novelty or difference from generally received statements is here introduced. Further, all minor influences affecting the mechanics of the pelvis are thrown aside out of consideration; and this for two reasons—namely, that they are unimportant when compared with the great forces and important principal parts considered; that is, that though undoubtedly useful and influential in their own spheres, their influence on the great questions to be now discussed must be so inconsiderable that they may be neglected in a young investigation, the great elements of which are first to be settled. In addition, they would, if considered, be found to introduce so many difficulties and complications as to remove the subject almost, if not altogether, from the field of investigation. Among this class of points are the relations and positions of single muscles, ligaments, or the various parts of bones.

In observing the influence of the mechanical conditions of the iliac beams on the development of the contour of the pelvis, it is of course necessary to confine our attention to the ilia while undergoing growth and change, and before they have become firmly solidified into their permanent shape. This period extends from childhood, or from the commencement of walking to the age of about twenty years. In these early years the os innominatum is divided into three parts—the ilium, ischium, and pubis—all connected by cartilage. The sites of connection are the acetabula, and the sides of the pubic arch. In the latter positions, ossification and consolidation are said to take place about the age of seven years; but in the former, this is not effected till the age of about twenty years. It may therefore be held that, till the age of twenty years, the pelvis may be, to a great extent, moulded by the strong forces to which it is subjected, or that its mechanical conditions, as they are less stable, are more influential and important than afterwards.

During early life, the bones are more susceptible of physical influences than afterwards; for they are more elastic and flexible, and are believed to contain less earthy matter than in adult age.[1]

[1] Regarding the proportions of earthy to animal matter in bones of different ages, chemists seem not to be quite agreed. "It is usually stated," says Dr Humphrey (*On the Human Skeleton*, Cambridge, 1858, p. 5), "on the

The pelvis, during its growth, is subjected, in the manner to be afterwards described, to very powerful forces, and, at the same time, it also undergoes considerable changes of shape. It will be shown that these changes of shape correspond to the forces in every ascertainable respect. But before proceeding to show the relation of the forces to the shape produced, it is necessary to say a few words by way of illustrating how mechanical forces affect the shape of healthy bones.

It is surely indisputable that the healthy growing pelvis, as a whole, with its joints and with the Y shaped cartilages separating the cotyloid ends of the three parts of each os innominatum, is greatly under the control of the great forces to which it is for long periods subjected: and this admission is sufficient ground for the explanation of its development to be afterwards given. A somewhat apposite illustration of this kind of change of form is found in the spinal column, which in the young child is almost straight, but, under the influence of the weight to which it is subjected, assumes the curves natural to it in adult age.

But it is quite consistent with our general knowledge of the physiology of bone, that, under powerful and continued forces, even the healthy bones themselves undergo changes of form.[1] The human skeleton is so arranged as to have, in the adult at least, sufficient power to resist almost every tendency to change of form from this cause. But, even in the adult, the weight of the body acting at an extraordinary advantage on the neck of the femur, effects in it a slow change of shape, so that it is virtually bent upon the shaft, gradually forming with it a less and less obtuse angle, and from this and other causes combined, it becomes more and more liable to fracture.

The iliac beam may be regarded as a long bone, strengthened by the apposition of its ala. The weight or force to which it is subjected acts upon it at its two extremities, and not in the direction of its length, and with a degree of vantage not to be observed in any other bone of the body. It does, while growing, change in form under these forces, and, I believe, in consequence of them. A like

authority of Davy, Schreger, and others, that there is a progressive and considerable increase in the earthy constituents of the bones with advancing years. This, however, would seem to be by no means universally true. Dr Rees finds it to be the case with regard to the long bones, and the bones of the head; those of the fœtus not containing the excess of earthy matter which he discovers in those of the adult. But the bones of the trunk in the fœtal skeleton appear, from his analyses, to be as rich in the proportion of earthy matter as those of the adult."

[1] That this pressure is without influence in the healthy skeleton appears to be the view expressed by Mr Moore, in a valuable paper on this subject, published in the *British and Foreign Medico-Chirurgical Review* for July 1857. "But (he says) it is surely erroneous to say that bones depend upon pressure for their regular development. Undue pressure may deform them, but not that which they are made to resist: had they no power of growing into a definite shape, and maintaining it, they would be incapable of bearing the very forces to which they are ordinarily subject."

change occurs in other long bones similarly treated, as in the femora of young lads who ride much on horseback.[1] Moreover, when the iliac beams are inordinately subjected to the natural forces in youth, their bending increases to an abnormal extent, as happens in factory children who have never suffered from rachitis, and whose skeletons present no evidence of the previous existence of the disease.[2]

In the field of pathology many illustrations occur, under the most varied circumstances, of the great influence of long-continued though slight mechanical forces in changing the shape of healthy bones.[3]

It is indeed inconceivable that elastic living tissues should endure powerful and continued pressure without being greatly and permanently affected by it. "The shape (says Dr Humphrey[4]) of the bones (and here it may be remarked that the uniformity with which 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. The effect of its operation may be observed in a variety of ways. Thus the modelling of the cranial, thoracic, and other bones upon the parts enveloped by them must be, in some measure at least, a result of the pressure of those parts upon the osseous material in its soft, growing state. The furrows and channels of the bones are, in like manner, partly originated and preserved by the pressure of the tendons, nerves, and vessels upon them. They do not exist when these are absent; and they disappear, becoming filled up, when these are removed. The curvatures of the bones, though chiefly attributable to the forces of development, may also, in some slight degree, be owing to the influence of pressure; some to the pressure of adjacent organs; some to pressure caused by the action of the muscles pulling upon them in the fœtal state, or by the weight of the body compressing them afterwards. It has been before remarked, and may be again mentioned in connection with this subject, that the bones are, as a general rule, most curved in those

[1] For a variety of facts illustrative of this subject, see Soemmerring, *Traité d'Osteologie* (French translation by Jourdan, p. 23).

[2] The converse of this appears to be true. Hubert (*loc. cit.*) makes the following statement:—"Ainsi chez une naine âgée de vingt et un ans, idiote, bien constituée d'ailleurs, mais qui n'avait jamais pu marcher, Nægele a trouvé le bassin semblable, pour la forme et la grandeur, à celui d'un enfant de sept à huit ans."

[3] See Rokitansky's *Pathological Anatomy* (Sydenham translation, vol. iii., passim), for a description of the effects of distortion of the spine on the shape of the pelvis.

[4] *Treatise on the Skeleton.* Cambridge, 1858. P. 48.

persons whose muscular strength is greatest—that is to say, when the pressure upon them resulting from muscular action is greatest; weak persons, on the contrary, provided they be not rickety, have, for the most part, comparatively straight bones."

During their growth—that is, from early childhood up till about the age of twenty—the iliac beams are subjected to two great forces. These forces are susceptible of most advantageous easy study, if we assume the body to be standing in the erect position. One of these forces is exerted by means of the superior or posterior sacro-iliac ligament passing upwards and outwards from the posterior rough portion of the lateral articulating surface of the sacrum to the corresponding portion of the ilium between its auricular surface and the posterior processes. The other force is applied through the head of the femur to the acetabulum, and (confining our attention to the ilium) to that part of the iliac bone contributing to the formation of the hip joint.

During the first twenty years of life the acetabular extremity of the ilium or iliac beam is joined to the neighbouring portions of the pubis and ischium by cartilage only, and therefore forces acting upon it may be more safely regarded separately, or as distinct from their action on the rest of the acetabulum, than if the cotyloid cavity were a solid cup of bone. Cartilaginous union even must be admitted to introduce new modifying forces for consideration; but even were the acetabulum formed of solid bone, the change would not essentially alter the direction or action of the force affecting the pelvis through the femora,—a point which will be more evident as we advance, and especially when the evidence afforded by observation of the malacosteon pelvis is properly considered.

The two great forces are opposites of one another, and equal to one another, as action and reaction are. When regarded as pressures, or devoid of momentum, they are severally equal to the weight of the half of all those parts of the body above them, if the body be supported on two limbs. But if the body be supported on one limb, as is for brief periods at least often the case, then the forces are doubled; and to this the weight of the limb not supporting the body is also added. But the forces are subjected to great variations on the side of increase if clothes and burdens are taken into account. These, however, are inconsiderable, compared with the great and sudden augmentations when momentum is given to the weights producing the forces, as happens in jumping, and to a certain extent also in running and walking. From these considerations, it is apparent that the forces are, in long-continued daily action, always considerable and often very powerful.

The increase of the forces when momentum is communicated to the body, as in walking or running, must be of great importance from its amount and the frequency of its application. But the great and sudden increments produced by shocks, as in jumping, falling on the feet, and such like, however important in other respects, can

have no great influence on the development of the contour of the pelvis. Such shocks are sometimes the cause of fracture. From this accident the pelvic circle is often saved by the insertion of three joints in it, and especially by the sacro-iliac joints, where all the ordinary arrangements for the diminution of the effects of a blow or shock are in play. In practice, however, this bony circle is found to be amply protected, for it is seldom broken except by direct violence applied to it. Nature has warded off danger to its integrity by placing the neck of the femur in the line of the shocks or blows from which it would otherwise run most risk. This neck of bone is generally a weaker part, and frequently the weakest part subjected to risk of fractures, and therefore the first to yield,—a circumstance which prevents the far more dangerous fracture of the pelvis.

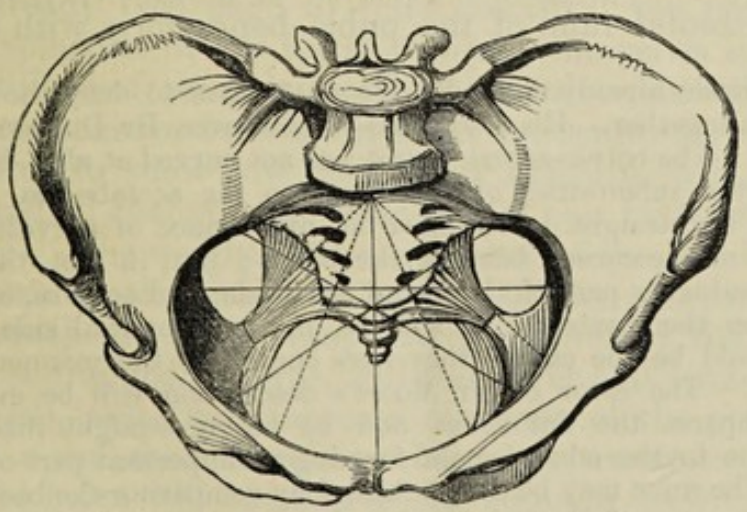
The direction of the chief force is, like that of all weights, vertical. It is transmitted from the sacrum to the posterior parts of each iliac beam, as already said, through the strong superior posterior sacro-iliac ligament. As this beam is not vertical, but directed downwards and outwards, and as in its course it is supported on the auricular facet of the sacrum as upon a fulcrum, it is evident that the force acting upon its upper portion will tend to draw it inwards, and therefore to throw the lower or acetabular end outwards. That the weight of the body acts in a vertical direction on the sacrum requires no proof. Its effects are seen in the vertical depression which this part suffers in deformities of the pelvis. Equally self-evident is the direction of the force acting on the upper part of the iliac beam, and any one may find this also confirmed by observation of the deformities of the pelvis. To produce equilibrium the reacting forces must be equal and contrary. They are applied to the lower end of the iliac beam and the cotyloid cavity. In order to resist the vertical force downwards, there must be a corresponding reactionary force upwards; and in order to balance the force throwing outwards the lower end of the beam, there must be a force inwards. The combined forces will act in a direction upwards and inwards. The upward force is easily accounted for: it is the supporting of the weight of the body. The inward force cannot be supplied by the pubic bones; these can only act to some extent as a tie-beam to fix the lower ends of the iliac beams. The direction of the conjoined forces is indicated by that of the neck of the thigh bone, and the inward force is supplied by the enormous muscles and some of the ligaments which are in action in the erect position, and this with such force as to keep the head of the thigh bone securely in the cotyloid cavity,—a result quite impossible without very powerful inward pressure. If further proof be demanded of the upward and inward direction of the force applied to the lower end of the iliac beam, it is easily found by a reference to the malacosteon and rickety pelvis. Another illustration we propose to give in a separate discussion of the oblique-ovate pelvis. In the malacosteon pelvis the direct upward and inward direction of the movement which the acetabulum has undergone is

proof of the force's direction. In the rickety pelvis the acetabulum is also displaced upwards and inwards as far as the iliac beam is concerned, although other peculiarities in the history of the production of the deformity, especially the anatomical conditions of early life, modify the general direction given to the acetabula by the pressure of the femora. These peculiarities it would be out of place here to enter upon.

That the lower ends of the ilia must have, during their growth, this tendency outwards, is shown also by the fact, that they are not forced inwards by the reacting force exerted on them through the femurs. When the healthy mechanism of the iliac beam is perverted by destruction of the sacro-iliac joint, and the tendency outwards of its lower end is thus annihilated, then the long-continued powerful pressure upon the acetabulum is unresisted by any counteracting force, except the elasticity of the bone: it pushes it inwards, and the result is, the production of the pelvis of Nægele if the joint does not exist on one side only, and of the pelvis of Robert if the joint is absent on both sides. It is likewise observed, that increase of weight applied on one side of the pelvis is accompanied by a corresponding and then morbid, because unsymmetrical, increase of effect on the side most powerfully acted on. The evidence in proof of this last statement may be drawn from various sources. Meantime, it is sufficient to refer to Rokitansky's observations, above cited, and the case of Wilkie in the Memoir of Hubert, and others.

Between infancy and adult age the pelvis not only grows in size, but gradually undergoes considerable changes in shape. In early life, the antero-posterior diameter of the brim is greater than the transverse. In the adult, the opposite is the case. In early life,

Fig. 1.

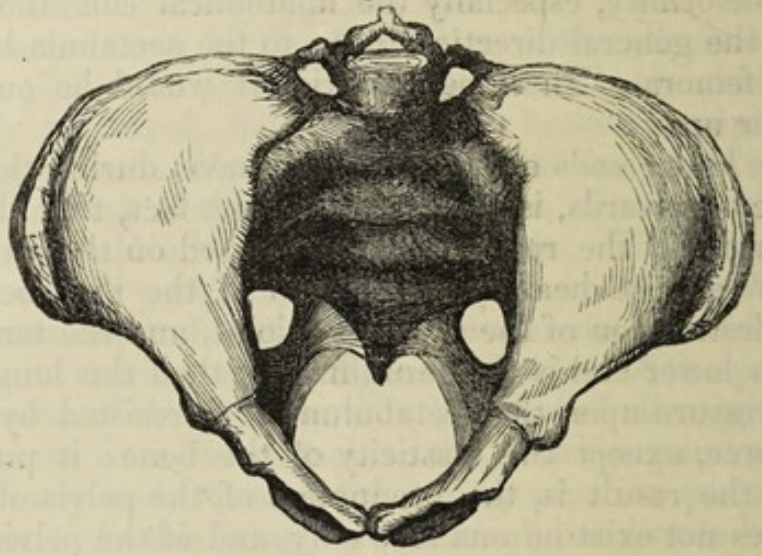


Pelvis of Adult Female (after Dubois).

the sacrum is much more nearly vertical in the direction of its length than in the adult. In early life the ilium is nearly a flat bone, and almost straight from the posterior tuberosities to the

acetabulum—that is, in the line of the iliac beam. This may be regarded as its spontaneously assumed developmental shape. In

Fig. 2.



Pelvis of a Young Child.

the well-formed adult female the comparison of the iliac beam with that of early life is complicated by the thickening which takes place at or opposite the auricular surface, and near the acetabulum; but, disregarding these, it will be observed to be curved like the segment of a large arc. This curvature is the result of the direction inwards and upwards of the articulating surface above and behind its auricular portion, and of the direction inwards and downwards of the part adjoining the acetabulum. The curvature[1] is not exactly circular, but is greatest at the thinnest or smallest part of the beam, namely, a little below the sacro-iliac joint, and a little above the acetabulum. This corresponds to the extremity of the greatest bisiliac or transverse diameter of the brim of the pelvis. In early life the horizontal rami of the pubic bones form with one another

[1] In his article already cited, Mr Moore appears to deny the occurrence of this change altogether. His words are—"Moreover, Dr Duncan's explanation is misapplied. The cotylo-sacral beams are not curved at all. From their extremities at the tuberosities of the ilium to the acetabulum, although not vertical, they are straight. They have an appearance of curvature from their forming part of the curved brim of the pelvis; but, in fact, they spread out below into the higher part of the broad acetabula, and acquire, as they spread, a concavity on their external as well as on their internal side,—not a convexity, as would be the case if they were curved in the manner described by Dr Duncan." The error of Mr Moore's description will be evident to any one who compares the flat ilium, and its nearly straight iliac beam, with the same bone in the adult female, forming an important part of the circle of the brim. The same may be demonstrated by comparing the bisiliac or largest transverse diameter of the pelvis with the diameter posteriorly between the sacro-iliac joints, and anteriorly between the acetabula. It must be admitted that, in many masculine pelves, approaching closely as they do to the infantile type, the curvature of the iliac beams is scarcely appreciable; but my whole object is to explain and account for the large and highly-developed female pelvis.

a much more acute angle than in the adult. In the latter the increased distance of the acetabula from one another is followed by a reduction of the anterior projection of the symphisis pubis; the horizontal rami of the pubic bones then pointing to one another at a very obtuse angle.

Such are the changes occurring in the pelvis during its growth. They are most truly epitomized in the statement that the transverse diameter of the brim is greatly increased at the expense of the antero-posterior or conjugate. This transverse enlargement is powerfully resisted by the pressure upon the acetabula. In spite of this it takes place, and the important question arises,—What is the mechanism which not only balances the lateral pressure on the acetabula, but overcomes it, separating them farther and farther from one another, and which moulds the female pelvis into its characteristic shape?

It must be evident to every one, that, as M. Hubert has well shown,[1] the increase of transverse diameter of the sacrum and the increase of length of the innominate bones, points in their natural developmental progress, have an absolutely essential place in the production of these changes, in so far as without them the pelvis would necessarily be much deformed. Mr Wood[2] has described these same changes in the sacrum and ossa innominata with some anatomical details regarding their osseous centres; but he goes further, and seems to think that the shape of the pelvis is regulated by these circumstances, and that the mechanical conditions I have described have little or no influence. It appears to me, however, as already said, that the powerful mechanical influences on the pelvis cannot be without importance, and that a decided change of shape is observed to take place in it, which is not accounted for by reference to natural development, but receives an easy explanation if we keep in view the physical forces referred to.

Having already (see page 5) fully described the power, direction, and peculiarities of the forces to which the pelvis is subjected, and the conditions of the pelvic bones themselves, as well as shown that these forces cannot be without great influence, very few words will be required to show how their study explains to a very great extent the gradual change undergone by the part between childhood and adult age. The weight on the upper end of the iliac beam tends to draw it inwards, the auricular portion of the sacrum being the fulcrum on which the beam rests. In proportion as the upper end of this beam is dragged inwards, will the lower end tend to be projected outwards, and the transverse diameter of the pelvis be increased. In a well-formed pelvis with large transverse diameter, this end of the beam will be observed to be more drawn inwards or flattened downwards than in a masculine pelvis or one without a large transverse measurement. The extravagant enlargement of

[1] *Loc. Cit.*, p. 21.
[2] *Transactions of Pathological Society*, 1856, vol. vii., p. 296.

the transverse diameter of the pelvis is prevented by the pubic bones and symphisis joining the lower extremities of the two iliac bones together. But a study of the rickety and malacosteon pelves will show how little influence these parts have[1] when not firmly ossified, in preventing the abnormal separation or approximation of the lower ends of the ilia. When the ossa innominata are completely ossified and healthy, then the influence of the pubic bones as a tie to connect and as a beam to keep separate, must be such as to render none else necessary. But before the ossa innominata are completely ossified, the great force preventing the extravagant transverse enlargement of the pelvis is the inward and upward pressure on the acetabula. Between these forces applied to the upper and lower ends of the iliac beams, is the auricular surface of the sacrum, acting as a fixed point upon which the two forces tend to bend the bone. The bone does slightly bend about midway between its auricular surface and its lower end.[1] But although it bends under the influence of these forces, its lower half is, as a whole, to some extent projected outwards. This bending and projection outwards form the characteristic changes undergone by the pelvis during its growth, and give the female pelvis its peculiar characters. In an elegant female pelvis these changes are best seen, for in it the bones are generally more delicate, and the iliac beam is longer than in the male. In a masculine pelvis the changes are less marked, for in it the bones are thicker, and stronger, and shorter, and earlier consolidated with one another. These conditions are at once the signs and the causes of the peculiarities of a masculine pelvis.

Further and irresistible evidence of this being a true explanation of at least a great part of the development of the pelvis, will be found in a study of the changes undergone by this part in rachitis and malacosteon, and in ossification of one or both sacro-iliac joints.

ILLUSTRATION AND CORROBORATION OF THE PRINCIPLES ALREADY LAID DOWN, DERIVED FROM THE STUDY OF THE PELVES OF NÆGELE AND OF ROBERT.

Before entering on this subject, I shall describe a characteristic specimen of the oblique pelvis of Nægele that is contained in my museum, and of which no account has hitherto, so far as I am aware, been published. It is only a fragment of an entire pelvis; the right ilium having been disarticulated, and the lower bones of the sacrum broken off and lost with it. The bones are well developed, and in this respect have nearly as much resemblance to those of a male as to those of a female.

There is no sacro-iliac joint on the left side, nor any trace of it.

[1] In my original paper this was not so correctly stated, the bending being said to take place at the sacro-iliac joint.

But its usual locality is to be detected at several parts, and the limits of the sacrum and ilium satisfactorily made out, by connecting them at those places, such as the brim of the pelvis, offering no indications. The union of the two bones is marked at some points merely by the different arrangement and direction of the lines on the surface; at others it is denoted by a very insignificant smooth ridge. Not only is the ossification complete at the usual site of the auricular surfaces, but behind this the posterior sacro-iliac ligament is replaced by a mass of bone continuous with the neighbouring parts, and undistinguishable from them; a point which probably has important bearings upon the origin of this malformation. The left ilium is flattened and pushed inwards, and consequently the symphisis pubis is displaced to the right side. A line at right angles to the transverse diameter of the sacrum, from the right side of its superior articulating surface, falls on the symphisis pubis. The sacro-pubic diameter is $3\frac{1}{2}$ inches; the diameter measured from the promontory of the sacrum to directly above the foramen thyroideum is $2\frac{1}{2}$ inches; the sacro-cotyloid diameter is 2 inches; the distance of the sacro-iliac symphisis from the symphisis pubis is $4\frac{1}{2}$ inches; the right oblique diameter 4 inches. The breadth of the base of the sacrum is 4 inches, and, dividing it at the anatomical centre, the breadth of the right half is $2\frac{1}{4}$ inches, of the left $1\frac{3}{4}$ inches.

A great variety of opinions and arguments has been brought forward regarding the cause of the peculiar deformity of the oblique-ovate pelvis. Most of these discussions, regarded philosophically, must be considered as remote from the subject. They refer to questions which, if settled, leave the real explanation of the matter unperformed. For instance, let us suppose it to be concluded that the sacro-iliac anchylosis is the chief cause (a conclusion which, in the sequel, I wish to support); it is necessary, before adopting this conclusion, to show how the effect results. This last part of the demonstration has been sketched only by a few recent authors. Without such a demonstration, the arguments regarding the cause of the deformity go no further than showing how some single point, imagined to be the essential one, is produced; as, for example, that the anchylosis is the result of intra-uterine disease, or that it is the result of abnormality, or absence of certain centres of ossification, etc.

The opinion of Nægele, that oblique deformity of the pelvis, and especially the anchylosis of the sacro-iliac joint, are not results of disease, but of abnormal development, has received the support of so many observations, and of so many distinguished authors,[1] that I am content to regard it, for the present at least, as determined. In the argument which follows, this class of questions is scarcely relevant.

[1] See Braun: *Lehrbuch der Geburtshülfe*, p. 424.

It is here assumed that, before childhood commences or not later than this time, the sacrum and ilium on one side are not separated by an articulation, and that the bones, especially the half of the sacrum on the affected side, do not grow in equal degrees with those of the normally developed side.

During growth, the whole pelvis is subjected to great forces, under the influence of which it moulds itself into its characteristic shape. Now, the question of causation resolves itself into this:—Why does the pelvis deviate from the ordinary shape, and assume the oblique deformity, when it grows and is moulded, not under normal conditions, but under the abnormal conditions of anchylosis of the sacro-iliac joint on one side, and atrophy of the parts of the bones joined? And the same question may be asked regarding the transversely contracted pelvis of Robert; the abnormal conditions in it being present on both sides of the pelvis, instead of on one side only, as in the pelvis of Nægele.

It is scarcely necessary to say that the atrophy of one side of the sacrum, and the less considerable atrophy of the corresponding os innominatum, form important points in the general form of an oblique pelvis. But it appears to me that the most important particular in the deformity of this pelvis, namely, its peculiar shape, has in most cases very little dependence on the atrophy. The occurrence of cases of oblique deformity without any atrophy, and with or without anchylosis of the sacro-iliac joint, is sufficient to show that atrophy is not essential to its production. Further, the abnormity of shape, or rather the pushing in of the side of the pelvis, its chief characteristic, is not in proportion to the atrophy; those pelves having the affected side of the sacrum very little less than the other, being as characteristically deformed as those with the greatest atrophy. It is to be noted that, in speaking here of characteristic deformity, I refer only to the bones of the affected side, not to the degree of diminution of the pelvic passage. This last will necessarily bear a direct relation to the atrophy of the sacrum. The deformity may be equally characteristic under different degrees of atrophy of the sacrum. The gravity of the deformity in practical midwifery is a different question, and is in proportion to the degree of diminution of the pelvic diameters.[1]

It is indeed more natural to suppose that the atrophy of the sacrum would tend to diminish the deformity of the os innominatum or increase the lateral bulging or expansion of the pelvis, inasmuch as the distance between the side of the atrophied sacrum and the symphisis pubis is less than the distance between the side of the fully developed sacrum and the same part. In other words, an os innominatum of natural length should form a greater lateral expan-

[1] This important distinction of characteristic deformity of the side of the pelvis from the degree of diminution of pelvic diameters, or change of shape of the pelvic passage, appears to me to have escaped the observation of M. Hubert, who has consequently arrived at faulty conclusions.

sion than natural, when the side of the sacrum to which it is attached is atrophied. In some cases, the os innominatum of the affected side has a length equal to that of the other side, but oftener it is shorter. This shortness must be of great importance in increasing the flattening. But that this shortening or atrophy of the os innominatum is not a chief cause of the deformity, must be conceded if we regard the circumstances, that in some cases it is not shortened, and that, instead of being deficient in length to reach the pubic portion of its neighbour, the symphisis pubis is generally displaced by the pubic end of the affected bone towards the healthy side. Moreover, in Robert's pelvis the flattening is observed when both ossa innominata are shortened, and when, therefore, there is no relative shortening, and therefore no shortening that can be made to account for the deformity.

I must refer the student to the papers of M. Hubert and of Mr Wood for the details of their opinions regarding the influence of atrophy or deficient ossific development in producing Nægele's deformity. I have preferred stating my own views in my own way, and so as to bear on the reasonings of these gentlemen, to preparing a methodical and detailed answer to their arguments, which might degenerate into at least the appearance of controversy. I shall only say that the views already expressed regarding the normal mechanism of the iliac beam, in which mechanism the sacro-iliac joint is an essential part,—views with which MM. Hubert and Wood nearly altogether coincide,—are such as to render it impossible to hold that it can be destroyed without affecting the shape of the pelvis. If the views of M. Hubert and Mr Wood as to the importance of the atrophied condition are correct, then the anchylosis must be regarded as of little importance; a conclusion, it appears to me, altogether inconsistent with the powerful agency of the sacro-iliac joint in the development of the healthy pelvis. In his diagrams of Nægele's pelvis, Mr Wood has not represented much atrophy of the sacrum or ilium, and it appears to me that, in any case of oblique pelvis, if the os innominatum retain its unnatural shape, the complete absence of atrophy will not destroy the characteristic obliquity.

Accordingly, as modern research advances, the importance of the joints of the pelvis becomes more and more evident. They are now regarded as contributing not merely to the safety of the structures of the body, by their action, along with numerous other joints, in preventing mechanical injury from various forms of violence; to the prevention of shock to the nervous system from similar causes; to the expansion of the pelvic passage in parturition, but also to the development of the healthy pelvis into its perfect form. In his remarks on the probable cause of oblique deformity, Nægele makes it appear that he suspected that the absence of the sacro-iliac joint was of more importance than he could by any means show it to be. He cites a memoir by Phœbus on deformities connected with congenital anchylosis, and the observation by Tourtual of a young Bohemian of

fourteen years of age, whose cranium was deformed, atrophied, and wanting the usual sutures. Tourtual's observation has had the fate of being cited as affording important suggestions by authors, who nevertheless refuse to recognise the importance of the anchylosis in producing Nægele's pelvis and Robert's. Fortunately, it led M. Dubois to push his investigations in a different direction. He had the advantage of examining, in the Museum of Pathological Anatomy of the Faculty of Medicine of Paris, a specimen of anchylosis of one of the squamous sutures, with marked flattening of the cranial vault in the part corresponding to the union. With the assistance of Professor Gavarret, he produced a theory of the action of the sacro-iliac joints in producing the healthy evolution of the pelvis, and also of their absence producing a morbid evolution of the same part. My attention was first drawn to this interesting subject on examining the views of these gentlemen. I soon became satisfied of the importance of the sacro-iliac joints and of their absence; but equally convinced that the explanation of this by Dubois and Gavarret was erroneous, and I advanced one of my own in two articles in the *Edinburgh Medical Journal*, already referred to. Since that time M. Giraud-Teulon, in his valuable work on animal mechanics, has broached another theory of Nægele's pelvis, founded on certain conditions of the sacro-iliac joints, which he believes to be present in cases where this deformity is being produced. He supposes that one of the joints, namely, that on the so-called healthy side, is more relaxed than the other. The sacrum, unequally supported between its points of suspension, is consequently drawn into an asymmetrical position in relation to the ossa innominata. It is separated from that which helps to form the relaxed joint, and brought nearer to the other. But as the sacrum is (he says) already in immediate contact with the latter, there will be powerful compression of the surfaces touching one another, and consequently more or less serious disturbance of the circulation and nutrition of the compressed parts. As a consequence of this, arrest of development of that half of the sacrum and neighbouring portion of ilium may be expected. On the lower side of the pelvis, or that having the less rigidity of parts in youth, abnormal changes will also take place. In the natural state, each half of the pelvis is subjected to a double force, one tending to increase the curve of the superior half of the circle, the other tending to destroy the natural curvature of the lower half-circle. If the circumstances of all the parts were the same (says M. Giraud-Teulon), the two forces could be considered simultaneously; but if we remark that the degree of their rigidity is far from being the same at different periods of life,—that in the first fifteen years the anterior or lower arch is scarcely solid, while the posterior is already completely ossified,—we will naturally expect to find the second of these forces more frequently producing its result than the other, the cotyloid cavities yielding to the force pushing them towards the antero-posterior vertical plane. In Nægele's pelvis, the symphisis

pubis is a point fixed, by its being partly formed by the healthy os innominatum. It is only, therefore, the cotyloid cavity of the affected side that is pushed inwards.

The theory of M. Giraud-Teulon, while it is very ingenious and worthy of consideration, seems to me not to demand further discussion at present, on account of its being inapplicable to the conditions at present believed to exist in the pelvis of Nægele which it is intended specially to explain. Instead of different degrees of relaxation of the two sacro-iliac joints, there is believed to be, in cases of Nægele's pelvis, complete absence from the earliest periods of one joint, while the other joint is believed to be perfectly healthy, and has never, so far as I am aware, been shown to be otherwise. This difference between the assumptions of the theory and the phenomena to be explained, must be removed before the explanation can be accepted, and renders it unnecessary to point out minor difficulties at present.

It has been very illogically argued, as conclusive against all theories of Nægele's pelvis, in which anchylosis is an essential condition, that cases of oblique deformity occur where there is no anchylosis; and, *vice versa*, that cases of normal pelves occur where there is anchylosis.

It is well known that cases of oblique deformity of the pelvis, more or less resembling Nægele's, are observed without any anchylosis. Such cases often do not very closely resemble the characteristic deformity, and can scarcely do so, seeing that they sometimes do not at the same time present the atrophy so important in it. But, supposing the resemblance in form were exact, and the anchylosis absent, these circumstances would afford no ground for denying the influence of the anchylosis in Nægele's pelvis, unless it were inconceivable that any other combination of circumstances could produce the oblique deformity except those producing Nægele's deformity. This is very far from being the case. But while it is so, I venture to express a belief, that the establishment of the true theory of Nægele's pelvis will soon lead to the discovery of the causation of oblique deformities of all kinds.

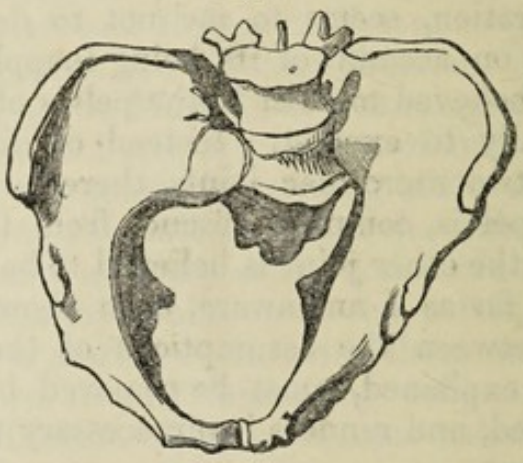
It has been truly alleged that cases occur of pelves with sacro-iliac anchylosis, and no further deformity. These cases are not common, and are illustrations of anchylosis occurring after complete development, not before it. If a case can be adduced of anchylosis in early infancy, in which the pelvis has grown, under the usual conditions, into its healthy shape, it might be fatal to the theories in which anchylosis is a postulate. But this is not to be feared.

If the theory of the natural development of the pelvis adduced in a former part of this paper be correct, then it is very easy to account for the occurrence of Nægele's deformity,—a circumstance which, by a reflex action, strongly corroborates the original views.

Congenital absence of the sacro-iliac joint on one side is generally admitted to be an essential character of the deformity. If this,

then, be assumed, the explanation of the deformity of shape is very easy. For the iliac beam united to the sacrum, not moving or po-

Fig. 3.



Nægele's Pelvis.

tentially moving on it, loses all the peculiar mechanical relations which it has in a natural condition. The weight of the body on the affected side is transmitted to the head of the femur from the sacrum through an unbroken continuous bone. It is not conveyed, as in the natural state, to the upper end of the iliac beam; and therefore its action on that part, in tending to draw it inwards, is lost, as well as the contemporaneous opposite action on the lower end. Indeed, it is the loss of this latter that is essential. For the upward and inward pressure of the femur is unresisted, and this great power prevents the expansion of the pelvis which the natural mechanism of the iliac beam produces; and in some cases it may gradually force the bone to bend slightly inwards between the position of the absent sacro-iliac joint and the acetabulum. Not only is the force exerted on the acetabulum unresisted, it is also greatly increased in amount above its natural state. This increase depends on the acetabulum of the affected side being more nearly in the same vertical line with the weight resting on the sacrum, than the same part on the other side. This circumstance may safely be said to make the affected side bear, if the body be evenly balanced on the pelvis, two or three times the amount borne on the opposite side.

This result of the iliac beam being deprived of its natural arrangement, produces as secondary phenomena other changes in the pelvis, except perhaps the atrophic conditions, which are probably in most cases congenital defects, but which are not invariably present to a marked extent, and without which the characteristic form is produced. The advancement upwards and inwards of the acetabulum pushes the symphisis pubis towards the opposite side, and aids in throwing the lower end of the iliac beam of that side farther outwards than is natural. These changes assist in producing the

appearance of twisting of the pelvis; the anterior surface of the sacrum not looking forwards to the displaced symphisis, but towards the hip-joint of the affected side.

It is to be observed, that as the deformity increases, or, in other words, as one side of the pelvis is expanded and the other is not, the weight on the abnormal side, or force assisting in the evolution of the form of the pelvis on that side, is increased beyond its natural proportion, while on the other side it is diminished. This arises from the sacrum, or weight to be supported, being on the affected side much nearer a vertical line passing through the acetabulum than on the other; a circumstance which must add to the force producing the deformity on the affected side, and indirectly produce by the pressure through the symphisis the deformity on the so-called healthy side.

After the discovery and exposition of secondary or efficient causes, it would not displease even Bacon to find reference made to final causes. This course I intend to pursue, believing that, in the present case, the study of final causes is not only important in regard to the arguments generally derived from them, and into which I do not propose to enter, but also useful in the way of confirming the general accuracy of the theory of the efficient causes already detailed.

Nature has provided the human pelvis with two sacro-iliac joints. The most important known functions of these joints are, to secure the normal development of the pelvis, and to prevent the risk of injury to its integrity from external shocks.

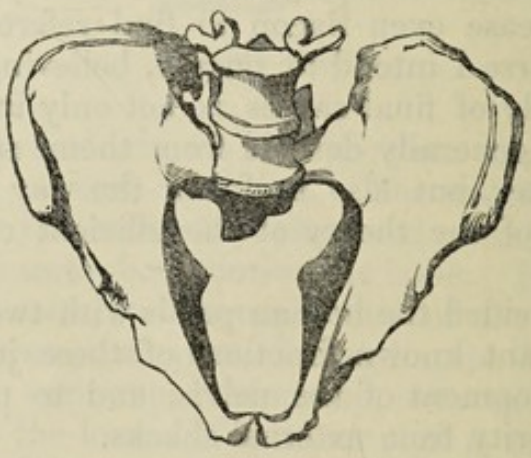
When the sacro-iliac joints are absent, their function of assisting in the production of the natural shape of the pelvis is of course annihilated, and no compensating power is introduced by nature to obviate the evil effect of this loss. A deformity, in short, is the result. But it appears to be otherwise with the function of preserving the pelvis from the dangerous effects of external violence. Clinical experience does not afford any information as to the special liability of oblique pelves to fracture; and we can entertain little hope of this point being soon sufficiently illustrated by examples to enable us to extract lessons from experience. But a study of the peculiar form assumed by oblique pelves easily discovers in it arrangements which diminish, or perhaps entirely obviate, the evil that might otherwise result from the loss of this second function of the sacro-iliac joints.

The loss of the development function of the sacro-iliac joint issues in the weight of the body being disproportionately largely laid upon the affected side the sacrum being, in a direct transverse line, nearer a perpendicular passing through the acetabulum of that side than of the other. The weight of the body is liable at any time to be changed from a pressure into a blow, against which this side has not the protection of the joint. But, to resist the blow, it is strengthened by the very deformity. The arch of the side of the pelvis is destroyed,

and the blow is conducted to the head of the femur by an almost straight column of bone; or, the blow is inflicted on the end of a lever equal in length to the small distance between the line of force passing through the sacrum and the support in the acetabulum. On the unaffected side, with its large arclike curve, the increased or unnatural distance between the line of force passing through the sacrum and the acetabulum, is compensated for by this very distance leading to an unnatural amount of the force being expended on the other side, as already said.

The transversely contracted pelvis of Robert has for its characteristic conditions, anchylosis of the sacro-iliac joint, flattening of the sides of the pelvis, and atrophy of the sacrum and of both ilia. Its

Fig. 4.



Robert's Pelvis.

morbid conditions may be regarded as being primarily the same as in the oblique pelvis of Nægele; only, both sides are affected instead of one. This renders the pelvis symmetrical. For the natural function of the iliac beam being lost on both sides, the unresisted, and therefore unnaturally powerful, pressure on the acetabulum will affect each side equally, and there will be no displacement of the symphisis towards one side or of the sacrum towards the opposite. This pelvis affords as good evidence as Nægele's of the true mechanism of the iliac beams; for, their action being lost, the pelvis is not at all expanded during its growth, but contracted, and in the adult bears a strong resemblance in shape, as Scanzoni and others have pointed out, to the pelvis of the fœtus or young child.

I shall not enter upon the consideration of the bearings of this curious form of pelvis on the theory of pelvic development which I have advanced. This I have already done incidentally in the course of the paper, and the reflection of the intelligent reader will supply what is wanting better than I can. Indeed, to attempt it would require something so nearly like dry repetition, that its avoidance will not be more gratifying to the reader than agreeable to myself.

I shall only say, that the whole phenomena of Nægele's and Robert's pelves are explained by and support the theory of the natural development of the pelvis which I have supported, while they appear to me to be irreconcileable with, and therefore adverse to, all the other explanations of the phenomena hitherto advanced.

P.S.—It is my duty to record my obligation to Professor Elliot of Liverpool for some valued criticisms on this paper.

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