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THE

PATHOLOGY AND ETIOLOGY

OF

CONGENITAL CLUB-FOOT.

PARKER AND SHATTOCK.

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BY

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THE ARGUMENT.

Our argument is that the feet of the foetus occupy various positions during the course of intra-uterine life; and that this occurs in order that the joint-surfaces, the muscles, and especially the ligaments, be developed so as to allow of that variety of positions and movements which are afterwards to be natural to the foot; and we hold that when anything (mechanically) prevents the feet from assuming these positions at the proper time, or maintains them in any given position beyond the limit of time during which they should normally occupy such position, a talipes results. The variety of talipes will depend on the date of its production; its severity will be in direct ratio to the mechanical violence at work. If the inversion of the foot, which is normal during the earlier months of foetal life, be maintained beyond the normal period of time, the muscles and ligaments will as a consequence be adaptively short on one aspect of the limb, and too long on the other; a normal position of inversion will finally become a deformity. Talipes calcaneus is, we believe, produced in a similar manner; it occurs, however, later during intra-uterine life, when a flexed position of the foot is normal. Being thus less fundamental in character, it is also less severe, as a deformity, than varus.

⁂ The Authors are still pursuing the inquiry, and would gladly acknowledge any pathological material which in any way bears upon it.

R. W. P.
S. G. S.

May 20th, 1884.

"VARI IGITUR NON UNO MODO, SED PLURIBUS FIUNT."

Hippocrates.

THE

PATHOLOGY AND ETIOLOGY OF CONGENITAL CLUB-FOOT.

WE venture to offer the following observations as a contribution to the pathology and etiology of this common but still obscure disease. Although the paper embraces rather a wide field, we do not in any way consider it exhaustive. The more we consider the subject the more we appreciate the full significance of the Hippocratic teaching, "Vari igitur non uno modo sed pluribus fiunt;" and, while the outcome of our present study is to confirm the impression which clinical observation first gave us, that the deformity depends on mechanical rather than on pathological causes proper, we do not pretend to have explained all the methods in which a mechanical cause may act; nor, in a few exceptional cases, would we deny the agency of other causes, such as disorder or disease of nerve-centres, pathological deviations affecting the bones (*e. g.* absence of tibia, fibula), &c.

PATHOLOGY.

The observations are founded on a careful study of five cases of our own, of many specimens contained in the Museums of the Royal College of Surgeons of St. Bartholomew's, St. Mary's, St. Thomas's, Guy's, and University College, Hospitals, and on a study of the conformation of the astragalus in man and the higher apes.

CASE 1.—The specimens were removed from the body of a child aged 18 months who died in the East London Hospital for Children of tubercular meningitis. The child had first been seen as an out-patient when five weeks old; she was the subject of well-marked double congenital varus. Treatment by manipulation and plaster bandages was commenced at once, and some progress made; the child, however, ceased to attend, and when seen again fourteen months subsequently, at the commencement of her fatal illness, the feet were as bad as ever. A complete autopsy was made; but reference will only be made in this place to the spinal cord and the affected limbs.

The right foot was dissected so as to display the muscles and tendons *in situ;* and while the bones and ligaments of the other foot were specially studied, portions of each of the muscles and of the chief nerve-trunks were examined microscopically.

The spinal cord presented no naked-eye change, either externally or on section; there was no alteration in its consistence at any part, nor any change in its membranes, or in the spinal canal. It was hardened in a weak solution of chromic acid, frequently changed; the sections were stained with hæmatoxylin and with carmine, and with the two combined. They were mounted, some in dammar, some in Canada balsam. Many sections from each of the regions were examined under the microscope, but nothing abnormal could be seen anywhere. We may especially remark that the multipolar cells in the anterior horns of the grey matter were quite healthy in appearance, and normal as to number.

The popliteal nerve and its main divisions, prepared in the same manner as the cord, were also examined with a like negative result.

Portions of each individual muscle of the left leg, after hardening in spirit, were examined. The sections were stained, some with osmic acid, some with hæmatoxylin, and found to be perfectly healthy.

After removing all the muscles from the left leg we were struck by the fact that considerable force was still required to straighten the foot. On removing the anterior portion of the internal lateral ligament of the ankle, which was found to be firmly blended with the short plantar ligament—both of which ligaments were considerably shortened—this resistance was overcome. A bursa was found between the tip of the malleolus and the navicular bone.

The astragalus presents some remarkable deviations from the normal. Its trochlear surface is extended backwards as far as the posterior edge of the lower articular surface. The extent of this additional surface is still easily recognisable ; and it is clearly due to the condition of extreme extension of the ankle-joint. On the contrary, the extent of the trochlear surface is proportionately lessened in front, owing to the fact that it no longer forms part of the proper articulating surface. In the next place, the neck of the astragalus is lengthened and directed inwards with an unnatural obliquity; measured in the manner about to be described, this obliquity amounts to 53° (Fig. 1), as against the mean 49·6° in varus cases, and 38° in the healthy bone. The ar-

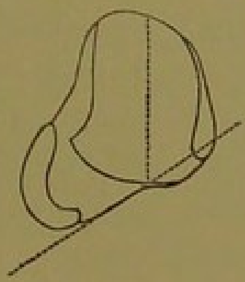


FIG. 1.—From an infant, aged 18 months, with varus (natural size). Obliquity of neck =53°.

ticular surface of the head is prolonged on its inner side ; and instead of being uniformly convex it is divided into two parts, the planes of which meet at an obtuse angle ; the inner and larger corresponds to the displaced navicular bone ; the outer portion, which looks forwards, is unopposed, instead of being, as in the normal condition, in contact with the navicular. The portions which are redundant, both on the head and on the trochlear surface, correspond in extent with the normal limits, but do not present the polished surface of the rest of the articulating areas, being covered with a layer of loose connective tissue. The internal malleolar facet is unrecognisable, doubtless because it too has ceased to form part of the proper articulating area.

The calcaneum lies in a position of exaggerated rotation inwards beneath the astragalus, a considerable portion of the upper posterior facet being uncovered and marked off from the rest by a low ridge, similar to that found on the head of the astragalus and above referred to. In consequence of the extreme extension of the ankle-joint this uncovered portion of the posterior facet articulates with the posterior border of the external malleolus. The inner portion of the posterior facet is continued into that on the sustentaculum. The plane of the cuboidal facet is directed unnaturally inwards, and its outer border is less prominent than usual. These results are due to a curving inwards of the anterior part of the bone from traction made upon it through the external calcaneo-cuboid ligament. We may also mention that the cartilage-basis of this bone is structurally continuous with the navicular, a condition alluded to by CRUVEILHIER in his 'Anatomie Pathologique.' We think the condition is comparable to that in which the digital phalanges are sometimes coalesced or connate.

CASE 2.—The left foot from an anencephalous fœtus at about the seventh month. We may especially observe that the inversion of the foot could not be completely overcome until all the ligaments passing between the several bones on the inner side of the foot had been divided (a matter of great importance in reference to treatment). The foot was in a position of well-marked varus. We could discover no deviation in the form of the astragalus, except that the angle of obliquity was considerably less than normal, being only 31° as against 38° the mean in health, and 49·6° in varus cases (Plate I, fig. 12). The calcaneum was normal. The right foot was normal.

CASE 3.—From an anencephalous fœtus of about the seventh month. Left foot in a position of extreme varus. Before dissection the inner border of the foot was capable of being brought up to the inner side of the leg; extension of the ankle beyond a right angle was impossible. On dissection the upper extremities of the tibia and fibula were found in their normal relative position to one another and to the femur, whilst the lower end of the fibula lay in a plane anterior to the internal malleolus, the transverse axis of the lower end of the tibia being directed forwards and outwards. It was evident therefore that the lower ends of the tibia and fibula had undergone a marked amount of rotation inwards. The internal malleolus is in contact with the navicular, and the navicular with the sustentaculum tali, a bursa intervening. The body of the astragalus maintains its proper position relatively to the tibia and fibula; the bone is in a position of full extension. The cartilage of the trochlea in front of the surfaces, actually in contact, is impressed by the fasciculi of the anterior ligament. *Band-like adhesions* exist between the trochlea and the opposed margins of the tibia and fibula. The navicular facet is divided into two, the respective planes being at rather less than a right angle to one another; the outer division is of small extent, and covered by the capsule of the joint; the inner one alone is in contact with the navicular. *The obliquity of the neck in this case is extreme*; as measured in the manner hereafter described it represents an angle of 64° as against the mean 49·6° (Plate I, fig. 9). On placing the calcaneum in an antero-posterior plane, its cuboidal facet lies at an angle of 45° with this plane, and the outer margin of the bone is rounded as described in Case 1.

Case 4.—From an undersized fœtus of about eight months, with talipes calcaneus of the right foot. The ankle did not admit of extension to a right angle. On dividing the tendons of the tibialis anticus and the extensor proprius hallucis extension-movement was increased, but division of the anterior ligament of the ankle was necessary before full extension was possible. Movements, especially of extension, in front of the transverse joint were also much limited. The outer and inner borders of the foot were convex towards the plantar aspect in all positions allowed to the foot, the summit of the inner curve corresponding with the junction of the first cuneiform and first metatarsal bones. *The astragalus presents no recognisable deviation from the normal form*, except that its fibular surface is vertically ridged down the middle, the anterior portion only corresponding with the malleolus in the fully flexed position of the foot. The angle of obliquity of the neck measures 33° (Plate I, fig. 14). The calcaneum is quite normal in all respects.

Case 5.—Removed from a child, born at seven and a half months, with imperforate rectum, death taking place on the eighteenth day. There was talipes calcaneus of the right foot, the left foot being but slightly affected. After dissecting away the muscles, the anterior ligament was found to prevent extension-movement at the ankle. The trochlear surface of the astragalus in this case is prolonged forwards on the upper surface of the neck of the bone, as far as the margin of the navicular facet. The inner malleolar facet is also prolonged on the inner side of the neck, nearly as far forwards as the limit of the margin of the navicular surface. The angle of obliquity of the neck measures 39° (Pl. I, fig. 15). The calcaneum presents nothing abnormal.

Case 6.—Fœtus at full term, with a sloughing spina bifida in lumbo-sacral region, and extreme varus of both feet. On the left foot there is a depressed, atrophied patch of integument over the external malleolus, and a second one further forwards over the prominent outer portion of the head of the astragalus; a similar condition exists on the right foot. On raising the skin in this situation, a distinct lenticular bursal cavity, about 7 mm. in diameter, is exposed, containing glairy fluid (a condition similar to that described by Volkmann and Lücke). The plane of the facet on the astragalus corresponding to the navicular looks directly inwards; the external portion of this facet is well represented, the planes of the two divisions meeting at a right angle; but the portion of the joint corresponding with it, though persistent, is separated from the rest by a delicate line of adhesion. A well-marked band of adhesion passes from the trochlea, at its line of union with the fibular facet, to the tibio-fibular junction from front to back. The obliquity of the neck amounts to 56°. Between the front of the trochlea and the capsule of the ankle-joint is a circumscribed cavity, separated by adhesions from the actual articulating area (Pl. I, fig. 10). The outer margin of the cuboidal facet of the calcaneum is rounded, as described in other specimens.

(For the opportunity of dissecting this specimen we are indebted to Mr. D'Arcy Power, Curator of the Museum of St. Bartholomew's Hospital.)

Etiology.

The significance of the foregoing details will be the better understood if we briefly advert to the causes which are usually invoked to explain the production of talipes.

These causes may be classed as—1. Nerve causes (leading either to paralysis or spasm of certain muscles). 2. Bone causes (consisting in malformations of the astragalus and calcaneum). 3. Mechanical causes (interlocking of parts, pressure due to environment, &c.).

1. *Nerve causes.*—By those who advocate this theory (*vide* the third edition of 'Holmes' System of Surgery,' vol. ii, p. 232) it is

argued that, because talipes ensues after certain recognised nerve lesions, a nerve lesion must therefore be the cause of those forms of talipes which are congenital, since the two deformities are so outwardly alike. This argument, they think, is strengthened by the fact that talipes is often associated with malformations of the nerve-centres (such as anencephalus, spina bifida, &c.). We feel bound to dissent from these views for many reasons. In the first place, the supposed nerve lesions have never been demonstrated. Apart from the fact that in our own case the nerve-centres and the nerve-trunks of the limb were perfectly normal, there are clinical facts which tell against the nerve theory of causation. The most important of these is that talipes is an accidental, and not an essential, sequel of paralysis. VOLKMANN has shown that the paralysed foot falls into a position of equino-varus by gravity; it is, furthermore, the position of perfect rest, which the foot assumes during deep sleep or during artificial anæsthesia; it is a position which the foot is very apt to assume after fracture, and, indeed, whenever the limb passes out of control of the will; moreover, the foot can very easily be prevented from assuming such a position. In cases of infantile paralysis we have noticed further that the foot, even when left to itself, does not always assume a talipedic condition, and when talipes does supervene there are other unmistakable signs of nerve lesion, viz. general atrophy of the limb, with lowering of temperature, conditions which are persistent through life, and which exercise considerable influence on the treatment. If we contrast these atrophic conditions with the well-nourished, warm limb of the majority of cases of congenital talipes, and if we further bear in mind the completeness of the recovery from the congenital deformity, the insufficiency of the nerve theory will, we think, be abundantly manifest.

If further evidence in this direction be needed it is to be found in the fact that congenital malformation of the nerve-centres occurs without the association of talipes, as is abundantly shown by the specimens of anencephalus preserved in museums; Mr. PEPPER has recorded ('Medical Press and Circular,' May 8th, 1878) a case of so-called complete absence of brain and cord associated with talipes calcaneus of both feet, among other deformities. In this case we should have to assume a negative action of the nerve-centres, a want of nerve-control, perhaps, if we would invoke a nerve-cause at all.

Of spina bifida we have seen cases without deformity of the feet, but with atrophy of the lower limbs, probably due to nerve change. We have seen cases, again, with atrophied and weakened limbs, and unilateral talipes, the opposite foot showing no tendency to assume a talipedic condition. In eleven consecutive cases of spina bifida which have been under our care, there was no talipes in seven. In one case there was marked double varus; in two double, and in one single calcaneus; while in almost all the cases there was more or less motor paralysis below the lesion, with evidences of want of nutrition.

Thus far we have used the term congenital talipes in its conventional sense, and in contra-distinction to the acquired or paralytic form. But we think it quite possible in a few cases that there may be a nerve lesion apart from such manifest conditions as spina bifida, &c. For very occasionally at the time of birth (and the same may be found in the fœtus at comparatively early ages), the limb is more or less atrophied —a condition which is especially observable when the atrophy is confined to one side. We must, however, confess that we have no direct observations on the nerve-centres in support of these views. They are derived solely from clinical observations of cases, and the results may very well be put down as due to mechanical causes, and belong to the same category of cases as intra-uterine amputation, &c.

2. *Bone causes.*—Most, if not all authors, have referred to and described changes in the form of the tarsal bones, and in the direction of their articular surfaces. There appear, however, to be still differences of opinion as to whether these changes are concurrent with or secondary results of the deformity.

Mr. William Adams, so long ago as 1852, described before this Society ('Transactions,' vol. iii, p. 455), and figured with great accuracy, certain deviations in form and position of the astragalus met with in cases of congenital varus. Subsequently, in his Jacksonian Prize Essay,[1] he gave the results of further investigations on the nature and bearing of these deformities, summing up his views thus:—" . . . the altered form of the astragalus, there-

[1] 'Club-foot: its Causes, Pathology, and Treatment,' 2nd edition, 1873, p. 159, *et seq.*

fore, I regard as the result rather than the cause of the deformity."

HÜTER[1] subsequently corroborated ADAMS' description of these deviations, but instead of regarding them as a consequence of the malposition he considered them to be its initial cause. ". . . . congenital club-foot, in my opinion, consists chiefly in a pathological alteration in the form of the bones, and especially in the form and direction of the joint surfaces which (alterations), however, are closely allied to the physiological fœtal form." He believed that the articular facets of the astragalus in newborn infants tend naturally to place the foot in a supine position, while in the adult these surfaces have become altered in direction and tend to place the foot in a prone position. As regards the shortened muscles, he thought that this was a natural defect in their development, the length of a muscle depending on the distance between its points of attachment.

DIEFFENBACH[2] from clinical observation had many years previously expressed the same opinion:—". . . . All small children have a decided tendency to club-foot. . . . . The child retains this as long as it is carried in arms and only gradually loses it on walking, when the weight of the body presses the soles of the feet flat to the ground."

Our own observations, both clinical and anatomical, coincide in the main with the descriptions given by these authors, and while we agree with HÜTER that the deviations in form are of a physiological type, we think with ADAMS that they are a consequence of the malposition, and not its cause, as HÜTER taught.

Contrary, however, to the statement of Mr. ADAMS (page 153, op. cit.) that the neck of the astragalus at birth is normally continued directly forwards, we find, with HÜTER, that the axis of the neck of the astragalus at birth is invariably directed forwards with a considerable obliquity inwards.

We have already described in detail the tarsal bones of our cases of talipes. As having an important bearing on the subject, we will now proceed to consider the conformation of the astragalus in the

[1] 'Archiv für klinische Chirurgie,' vol. iv, part 1, p. 125, *et seq.*; and 'Virchow's Archiv,' vol. xxv, p. 598.

[2] 'Ueber die Durchschneidung der Sehnen und Muskeln,' Berlin, 1842, p. 82.

adult and fœtus, as well as, for purposes of comparison, in the anthropoid apes.

Our attention has chiefly been directed to the extent and direction of the articular facets and to the obliquity of the neck of the astragalus. To determine precisely the degree of this obliquity, we adopted the following plan of measurement: the astragalus, with its trochlear surface upwards and horizontal, was placed beneath a fine thread fixed across it; a second thread was fixed at right angles to this along the mid line of the trochlear surface, parallel with its inner border; whilst a third was placed along the outer margin of the neck of the bone, so as to intersect the other two; the angle formed by the meeting of the two threads last described was taken as the measure of the obliquity of the neck. The subjoined woodcuts, from which, however, the transverse lines have been omitted, will further explain this.

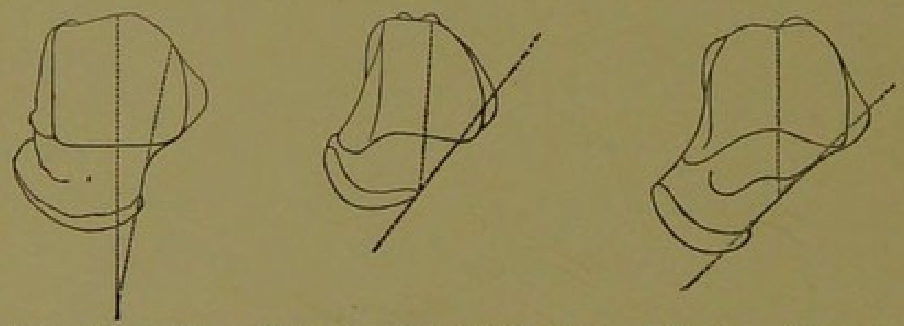


Fig. 2.—Human adult (reduced). Obliquity of neck =12°.

Fig. 3.—From a fœtus at term (natural size). Obliquity of neck =35°.

Fig. 4.—Ourang, young adult (reduced). Obliquity of neck =45°.

In this manner we measured the obliquity of the neck in twenty specimens of adult astragali taken promiscuously. We found the mean angle to be 10·65°. The maximum was 26°; in three cases the angle was so small that to measure it was impracticable. In two cases only the angle amounted to 20° and upwards; in twelve cases it did not exceed 12° (fig. 2), and in the majority was under 10°. In the fœtus from about the fourth month up to term the mean angle in eleven cases was 38°, the maximum 42°, and the minimum 35°. In three cases only did the angle exceed 40° (Fig. 3). In two cases of calcaneus this obliquity amounted to 33° and 39° respectively, being an average of 36°. In five cases of varus the mean angle was 49·6°, the maximum 64°, the minimum 31° (from Case 2), being an average of 49·6°. In an adult chimpanzee this angle measured 27°. In the ourang (young adult) it measured 45° (fig. 4).

From the foregoing measurements it is evident that an important difference in this respect exists at these two periods of life, and we submit that the modified form of the fœtal astralagus is to be associated with the high capacity for inversion enjoyed by the fœtal foot. In further evidence of this view, we may state that a comparative study of the astragalus disclosed a corresponding normal condition of obliquity in the anthropomorpha, in which animals the movement of inversion in the pes is one of the most ready of all the movements of the member; in association with the opposable hallux, the objects of this for purposes of arboreal progression are obvious. The end gained by this obliquity is clearly the increased range of the adduction of movement associated with inversion of the foot, in which movement the navicular is carried round to the inner side of the head of the astragalus, a movement which would be hampered or prevented were the inner border of the neck to lie in a sagittal plane. In the anthropomorpha it will be observed also that a line drawn sagittally over the middle of the trochlea, parallel with its inner border will lie altogether to the outer side of the navicular facet (Plate I, figs. 3 and 4, chimpanzee and ourang). The difference in this regard between the simian, the fœtal, and the adult astragalus in man will be plain from a study of figs. 1, 2, 3, and 4, Plate I; and the approximation of the foetal to the simian type will be further recognised by comparing figs. 2 and 4. We would draw especial attention also to the prolongation of the internal malleolar facet on the inner side and upper surface of the neck of the fœtal astragalus, an anatomical character not hitherto described. This prolongation is, almost without exception, to be found in the fœtal astragalus; sometimes it is so marked as to approach closely to the inner border of the navicular facet. Its presence is an interesting fact taken with its persistent condition in the apes, in which animals the same extension of this facet exists. We believe that the explanation of its development may be found in the obliquity of the neck of the astragalus, and in the flexed position of the foot during the later months of intra-uterine life, a position which in different degrees is maintained for a varying period after birth. In this position the facet will be found in accurate contact with the internal malleolus. In the great majority of adult bones this anterior prolongation has disappeared, a fact to be associated with the diminution in the obliquity of the neck as age advances, and the perfect assumption of the upright position.

In the adult ape, however, the facet persists, and with it the obliquity of the neck and the high capacity for inversion. The persistence of this facet in the anthropomorpha is explained by the permanent obliquity of the neck of the astragalus and by the fact that these animals are unable to maintain the upright position, and in walking or standing keep the joints of the lower limb in a greater or less degree of flexion.

In the human carpus, the presence of an *os centrale* has been demonstrated at an early period of fœtal life, such as forms a persistent carpal element among Simiæ and Rodentia. With such a passing character in the human carpus, this transitory conformation of the astragalus may, perhaps, be compared. In exceptional cases in which the assumption of the upright position is delayed (as in some cases of rickety incurvation of the tibiæ) we have observed a capacity for inversion to persist up to the third or fourth year of life.

Although from the foregoing evidence it is clear that the capacity for inversion may be considered as physiological during fœtal life, being the position to which the conformation of the bones is adapted, nevertheless, we think that the theory of malformation of the bones as the determining cause is untenable for the following reasons:

In all the specimens of varus (Case 2 excepted) there has existed a redundant portion of articular surface on the head of the astragalus to the outer side of the navicular bone, corresponding to the position occupied by the navicular in the normal condition as already described (page 7). A similar redundancy is observable also on the trochlear surface (and in particular cases in other joints also, *e. g.* "genu recurvatum," to which we shall again advert). These facts, we think, undoubtedly show that displacement of the foot has occurred at a period subsequent to the development of an astragalus of normal conformation. In Case 2 the conformation of the astragalus was quite normal —a fact which argues strongly against malformation of the bone as the cause or even an essential element of the condition.

Such variations appear to us to indicate rather a period of onset different in the two cases; and it may reasonably be presumed that the deformity in Case 2 is of comparatively recent date, and has depended most likely upon some accidental position of the limb, such as we shall presently refer to. Moreover, in the anthropomorpha, this peculiar conformation of the neck of the astragalus exists as a normal condition, and yet these animals are not talipedic.

As instances of displacements of the foot due to bone malformation, may be mentioned those recorded by Mr. Gould in the 32nd volume of these 'Transactions' ("Congenital absence of fibula and two toes, and talipes equino-valgus"); and by one of us in the 33rd volume of the 'Transactions' ("Congenital absence of radius from each arm, and of tibia from each leg"); and by many other observers.

3. *Mechanical causes.*—From the previous descriptions of the bones it will be seen that the changes in form of the astragalus vary considerably in amount, and may indeed be absent. With a view, therefore, to further elucidate this subject, we have turned our attention to a consideration of the positions of the lower limb during its development and growth, considering also some of the morphological questions thus raised.

It will be remembered that the limbs arise from the lateral parts of the trunk, as semi-lunar plates of the parietal mesoblast with its investing epiblast; and present, each, a dorsal (extensor) and a ventral (flexor) surface, the thumb and great toe being towards the head or pre-axial. As development takes place, the primary lappets, from being at first simple lateral extensions of the trunk, come to be folded ventrally or against the body of the embryo; the anterior with something of a backward, the posterior with something of a forward direction. The early subsequent alteration in position of the hind limb necessitates a rotation from the hip-joint downwards, by which the extensor surface of the thigh, leg, and foot are brought forwards, and their flexor surfaces carried backwards.

An examination of well-preserved fœtuses with the membranes still intact, shows that flexion of the knee, and inward rotation at the hip-joints, occurs at very early periods quite independently of the environment, as may be inferred from the large proportional amount of liquor amnii. By the increase in length of the lower limbs the feet, which at first were apart, come to meet over the lower part of the abdomen, and subsequently to cross, the normal position at this period, as may be well seen at about the fifth or sixth week, being one in which the hip- and knee-joints are flexed, and the crossed feet inverted (*vide* specimens, St. Bartholomew's Museum, 1205 ; St. Thomas's Hospital Museum, 1348), Plate II, figs. 1 and 2.

To judge from carefully-preserved specimens, however, it would appear as if this crossing of the limbs were occasionally interfered with. Thus, in a specimen (St. Mary's Hospital Museum, M. $\frac{c}{11}$, North Collection), Plate II, fig. 3, that of a well-nourished fœtus within its membranes, of about eleven weeks, the soles appear to have met so exactly as to interfere with the crossing of the legs; the feet, pressed against each other, are slightly flexed (talipes calcaneus), the sole of the right foot is arched, and receives the anterior part of the left, and its outer border is everted. There is abundant space within the membranes.

This is the only unequivocal specimen we have been able to find illustrating club-foot at so early a date in healthy fœtuses within membranes distended with the normal amount of amniotic fluid; and the deformity appears almost certainly due to the locking of parts one against another independently of surrounding pressure. Regarding this specimen, however, it is important to note that its age is computed at eleven weeks, the period at or about which, according to modern investigations,[1] the fœtus first begins to employ its muscles ; and it is hardly possible to believe that such a position could be long maintained after the period at which movements commence.

The occurrence of club-foot at early periods has been used as an argument against the mechanical theory of its causation, it being assumed that external pressure could have no influence in presence of the relatively large amount of liquor amnii present at such periods ; but we have seen no specimens which unequivocally demonstrate this early occurrence under such conditions. Most museums contain specimens of early fœtuses exhibiting various malpositions of the limbs, &c. All the specimens, however, which we have hitherto seen are fœtuses partially macerated, and which have clearly died before expulsion. These specimens present not only all kinds and degrees of club-foot, but all kinds and degrees of deformity of other parts. These results may certainly be attributed to com-

[1] Lusk, 'Science and Practice of Midwifery,' p. 99.

pression, and the manner in which they are brought about is by uterine contraction. When from any cause the fœtus dies, and is not shortly expelled, either the liquor amnii is absorbed or it escapes by rupture of the membranes, the fœtus remaining in utero; and among other changes, whether mummification or maceration, &c., &c., may be distorted as a merely passive substance in the most diverse ways (Lusk, op. cit., p. 287). That the uterine environment may affect the healthy fœtus may be concluded from those cases in which, during the later months of pregnancy, the uterus is found unusually small and firm, owing to deficiency in the amount of liquor amnii. Under these circumstances, owing to limitation of space, the fœtal movements are so plainly felt by the mother as to cause much discomfort (Lusk, op. cit., p. 278). This deficiency of the liquor amnii is of still further importance during the earlier stages of fœtal development, the adhesions (fœto-amniotic bands) which sometimes occur (*vide* specimen 3059,[1] St. Bartholomew's Hospital Museum) between the amnion and the surface of the fœtus being evidence of the close apposition of amnion and fœtus, and the early stage at which this occurs (Lusk, op. cit.). We have quite recently seen a male child (in other respects healthy) with a deep constriction on the right leg immediately below the knee-joint, just such as occurs from the encircling bands of adhesion noticed by most obstetrical writers, and referred to in both the papers noticed; the foot of the right limb was in a position of well-marked varus. The left limb was normal, but around the terminal phalanx of the great toe was a narrow well-marked furrow, like that encircling the opposite leg below the knee.

The deformity in club-foot may be so slight as to be readily remedied by nature, or so severe as to be overcome only by art. It would be out of place to describe in detail the various malpositions of the limbs, which may be present in the fœtus or child at birth; it is nevertheless highly important to notice them, as they are strictly parallel with clubbing or malposition of the foot. Indeed, there is nothing special to our thinking in the

[1] This specimen has since been fully described by Drs. Matthews Duncan and Hurry in the 'Obstetrical Society's Transactions' for 1884, where various fœtal malpositions from mechanical causes are related. Reference may also be made to an interesting thesis, 'Ueber amniotische Bänder und Fäden,' by Dr. Klotz, of Leipzig.

latter, and nothing which is not common also to other joints.

The best and least uncommon example that can be brought forward is the knee-joint. It at times happens that the fœtus at term is packed with the hips fully flexed, but the knees, instead of being flexed, are also extended, so that the feet lie opposite the head or face or neck. Mr. ADAMS (op. cit., p. 350), quoting LONSDALE, mentions such cases associated with breech presentation and talipes calcaneus. That the position is not a passing one, or one assumed by the fœtus at the time of parturition in adaptation to the requirements of the process, is plain from specimens showing this position some time before the full term. In Guy's Hospital Museum there are two fœtuses, one at the seventh month within its membranes, exhibiting this position.

A third specimen may be seen in the museum of the College of Surgeons, No. 3646A. These specimens further show that talipes calcaneus is no necessary association of this position. Such positions (of the knees) may be quite transient, being overcome after birth, partly by muscular action, and partly by manipulation. But, corresponding to that clubbing of the feet which is irremediable by nature, cases occur in which the extended position of the knees is rendered permanent by shortness of the muscles and ligaments and alterations in the joint surfaces. We have carefully dissected two such cases. In the first case the hips admitted of only limited extension; the knees were over-extended and incapable of being brought beyond the straight line. After all the muscles had been dissected away, no flexion of the knees was possible, and it was only after dividing the capsule, in front of the lateral ligaments, that flexion became possible. The articular surface of the femur had undergone alterations in shape, in adaptation to the position of over-extension in which the joint was fixed; around the impression for the inner condylar surface of the tibia the cartilage of the femur was covered by a layer of lax connective tissue, like synovial membrane, and similar to that found on the unused part of the articulating areas in Case 1.

In the second case the articular surface of the femur had undergone modifications in form, and the ligaments were adaptively shortened, so as effectually to prevent flexion, even after the other soft parts had been dissected away. In both cases the limbs were symmetrically deformed. Volkmann has named this condition "Genu recurvatum."

The same is true of club-foot; it exists in all degrees and in all varieties. In the mildest cases the bones may present no alterations in form, and the natural use of the part may suffice to restore its proper position. Some limitation of extension-movement at the ankle-joint is quite common at birth. The foot does not admit of being flexed beyond a right angle. This condition is but a mild degree of talipes calcaneus, and is due to exaggeration of the flexed position of the ankle-joint and to limitation of the movements, which are normal during the later months of fœtal life. Such a physiological condition affects both feet, and is part of the same group of conditions as the inability to fully extend the knees or the hips, first demonstrated as constant in the newborn child by Hüter, and all alike indicating a physiological shortness of muscles and ligaments in adaptation to the confined position of the limbs during intra-uterine growth.

The distinction between such a condition and that named talipes calcaneus is, we think, purely artificial, the more marked forms being due to still further exaggeration by environment of the position of the feet, normal during the later periods of intra-uterine life.

The lesser severity of this form of talipes may be associated in part with the later period of its production, and in part with the anatomical arrangement of the affected joint. Inversion is the position which the foetal foot most naturally takes, as being that to which it is physiologically adapted, and which may be looked upon as a simian character; it is the position assumed by the feet (hips and knees being flexed and the feet crossed and inverted, Plate II, figs. 1 and 2) in the earliest periods of their development, when nothing in the environment is present to condition it. It is a position, also, very readily assumed by the newborn child. Nevertheless it is as certain that normally during the later period of intra-uterine existence the feet are flexed on the legs. Such normal positions are represented on Plate II by figs. 5 and 6, which show a normal position of the lower limbs at the fifth month; and by fig. 7 at about the seventh month.

It becomes a question to determine how this change of position occurs. We submit that the change is one on the part of the foetus in adaptation to the increasing limitation of space. Such adaptive movements on the part of the fœtus, assisted by uterine contraction, are recognised (SIMPSON, LUSK) as the means by which malpresentations in the early periods of pregnancy are changed during the later months. Talipes calcaneus, we believe, therefore, to be only an exaggeration of the position, normal during the later period of intrauterine life, and due to abnormal confinement of the limbs within the uterus.

That exceptional positions of the entire limb *in utero* may lead to the production of talipes is well shown by a specimen in St. Bartholomew's Hospital Museum (No. 1226), Fig. 5.

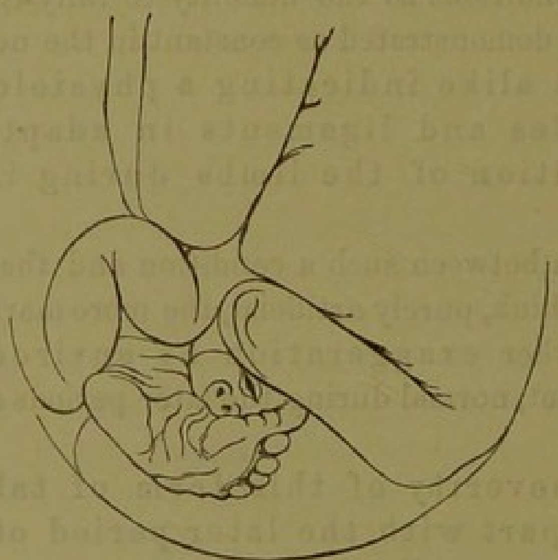


FIG. 5.—Fœtus, with Talipes varus, resulting from an accidental malposition of the left lower limb.

It is a healthy, well-nourished fœtus of about seven months, in position within the membranes and uterus ; the right lower limb is in a normal position ; on the left side the thigh is flexed, but the knee is extended, and the foot lies on the opposite cheek, in a position of marked varus, with the sole and heel opposed to the wall of the uterus. In this case there can hardly be any doubt that the talipes is the result of uterine pressure maintaining the limb in an accidental malposition and subsequently enforcing inversion of the foot.

As another example of highly-marked deformity resulting from mechanical causes may be mentioned the case figured by CRUVEILHIER in his Atlas ('Anatomie Pathologique,' 2nd livraison, plates 2 and 3). In this case both knees were extended ; the right foot was locked beneath the chin in a position of extreme varus; the left was also in a position of varus resting upon the prominence of the left shoulder. It is worthy of remark that both hands were "clubbed," but the condition, as is usually the case, was associated with absence of the radius from each forearm. Further cases of the kind are mentioned and figured by VOLKMANN (PITHA and BILLROTH 'Handbuch der Chirurgie,' vol. 2, p. 691).

Nevertheless, in the great majority of cases, to judge from clinical evidence, the general position of the lower limbs must be normal, for it is only in exceptional cases that we find other joints (than those of the foot) affected.

As a case of what perhaps is the ordinary intra-uterine position in double varus, we adduce the specimen represented in Plate II, fig. 8, from a preparation in St. Mary's Museum which we have had the opportunity of dissecting through the kindness of Dr. SILCOCK (M $\frac{A}{2}$ North Collection), though the disposition of the lower limbs in cases of varus is one on which further data are highly desirable. In this specimen a well-preserved fœtus within its membranes, of four or five months, apparently affected with a frontal encephalocele, the position of the hips and knees is normal; the sole of the right foot rests on the opposite buttock; the left foot crosses the dorsum of the right; both are in a position of well-marked varus; the fourth and fifth toes of the left foot are strongly adducted over the roots of the second and third; all the parts exhibit signs of compression. A detailed examination of the astragalus (which was in the extended position) displayed a division of its navicular facet, the larger division of which looked directly inwards and corresponded with the displaced navicular, the smaller outer portion being uncovered. The planes of these surfaces meet at an angle of 112°. The obliquity of the neck amounted to 44°, as against the mean 49·6°.

This astragalus, enlarged to double its natural size, is figured on Plate II, fig. 11. In the museum catalogue this specimen is described as an "abortion through arrest of development of the placenta."

An analysis of forty consecutive cases of congenital talipes varus shows that in nine cases the deformity was double; in seventeen single; while in the remaining fourteen cases it is not specified on which side it occurred. From these figures the frequency of one-sided deformity will be obvious. In none of these cases were the movements of any other joints either defective or exaggerated, evidence we think that the limbs have not occupied a faulty position. The large proportion of cases in which the deformity affects only one foot is, it seems to us, a strong argument against the supposition that the deformity is due to any inherent want of right development. On the other hand we think it may be readily understood if a mechanical mode of causation be invoked; the mode in which mere position of the feet may lead to the production of varus on one side is, we think, shown by such a specimen as that represented in Plate II, fig. 4, a healthy fœtus of about twelve weeks contained within its normal membranes (St. Mary's Hospital Museum, North Collection, No. 11). Here it will be seen that the crossing or free foot retains the physiological position of inversion, while the left foot in the act of passive crossing has met the inner side of the opposite thigh and lies protected in the flexure of the knee. In such a case it is obvious that compression would maintain or exaggerate the inverted position of the crossing foot, whilst its fellow would be guarded from pressure owing to its position. The possible varieties of position, however, which would lead to a like result are, of course, numerous.

As contrasting with the lesser severity of the lesion in calcaneus (which we believe may be explained by the comparatively late period at which it is produced, and by the anatomical condition of the parts concerned, as already mentioned) the condition of varus gives evidence of its early production in the great alterations in form of the astragalus and calcaneum; these are especially observable in the subdivision of the navicular facet of the astragalus, and the incurvation of the anterior part of the calcaneum; further evidence of early production is afforded by the shortness of the ligaments, and the adhesions sometimes found within the ankle-joint, as described in Cases 3 and 6, and which we have seen also in another extreme case in St. Bartholomew's Museum (No. 3511). The lesser degrees of talipes varus would seem to suggest that the original error in the environment has been transitory. The possibility of this is suggested by the different sources of the amniotic secretion; during the earlier period of intra-uterine life it is a transudation from the tissues of the fœtus and a plexus of vessels formed beneath the amnion; during the later period these sources become obsolete, and its further increase is due to the urinary secretion of the fœtus. It is thus possible that an early deficiency may be subsequently corrected.

With Volkmann and Lücke we think that the presence of areas of atrophic skin with bursæ beneath, as described in Case 6, situated over the most prominent points of the exposed aspects of the feet, confirms the view that the deformity is a condition enforced by the mechanical action of the environment; and additional proof of long-continued mechanical influence is afforded by the twisting of the leg-bones described in Case 3.

Good evidence of the effects of compression is further afforded by the hand represented in the adjoining figure. It was taken from

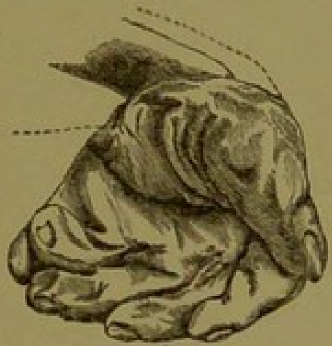


Fig. 6.—Fœtal hand, showing signs of marked pressure.

a fœtus exhibited at the Harveian Society in November, 1883, by Dr. Silcock. The abdomen was much distended by cystic kidneys; there were double talipes varus and subluxation of the hip-joints. Both hands were pressed flat as shown in the woodcut.

We think it may be assumed that the production of the deformity dates back from a period at which the inverted position of the feet is normal, and that the deformity results from the maintenance, with or without exaggeration, by the environment, of the early normal position—a position which it needs the least expenditure of force, either from within or without, to maintain. It will be remembered that the foot, when uncontrolled by muscular action as during sleep, in long-standing paralysis, and in the cadaver assumes the position of equino-varus, the position of perfect rest, as Volkmann, among others, has insisted upon; the explanation of this may, perhaps, be found in the fact that inversion is the earliest position the feet assume, and for which they retain an original and abiding conformation.

The comparative rarity of club-hand apart from deficiency of bones, is probably due, as explained by CRUVEILHIER, to the anatomical differences in the carpal and tarsal articulations; the great amount of mobility of which the hand is capable serving to obviate the serious effects which would be due to malposition in a member having a less range of movement. It may be suggested, further, that the position of the hands in the space between the thighs and the head serves as a protection against immediate pressure.

With regard to heredity, the whole question is so obscure that it is hardly profitable to enter upon it. Although cases of hereditary transmission of the deformity from parents to children do undoubtedly occur, yet in the vast majority of instances no such hereditary influences can be traced, and this is even true in instances where several children of the same family have suffered. The influence of heredity, however, may be invoked with equal force, whatever view of the pathology of the disease be adopted. But at first sight it may seem not a little remarkable that in some cases the deformity is transmitted along the paternal line; and it may be difficult to harmonise this fact with the influence of environment on which we have insisted. It need only be remarked, however, that the environment of the fœtus depends upon the fœtus itself, not less than upon the mother. For the most recent observations show that the liquor amnii may be considered throughout a fœtal and not a maternal product. Excess or deficiency in its amount may therefore be the result of a tendency inherited either from the father or the mother.

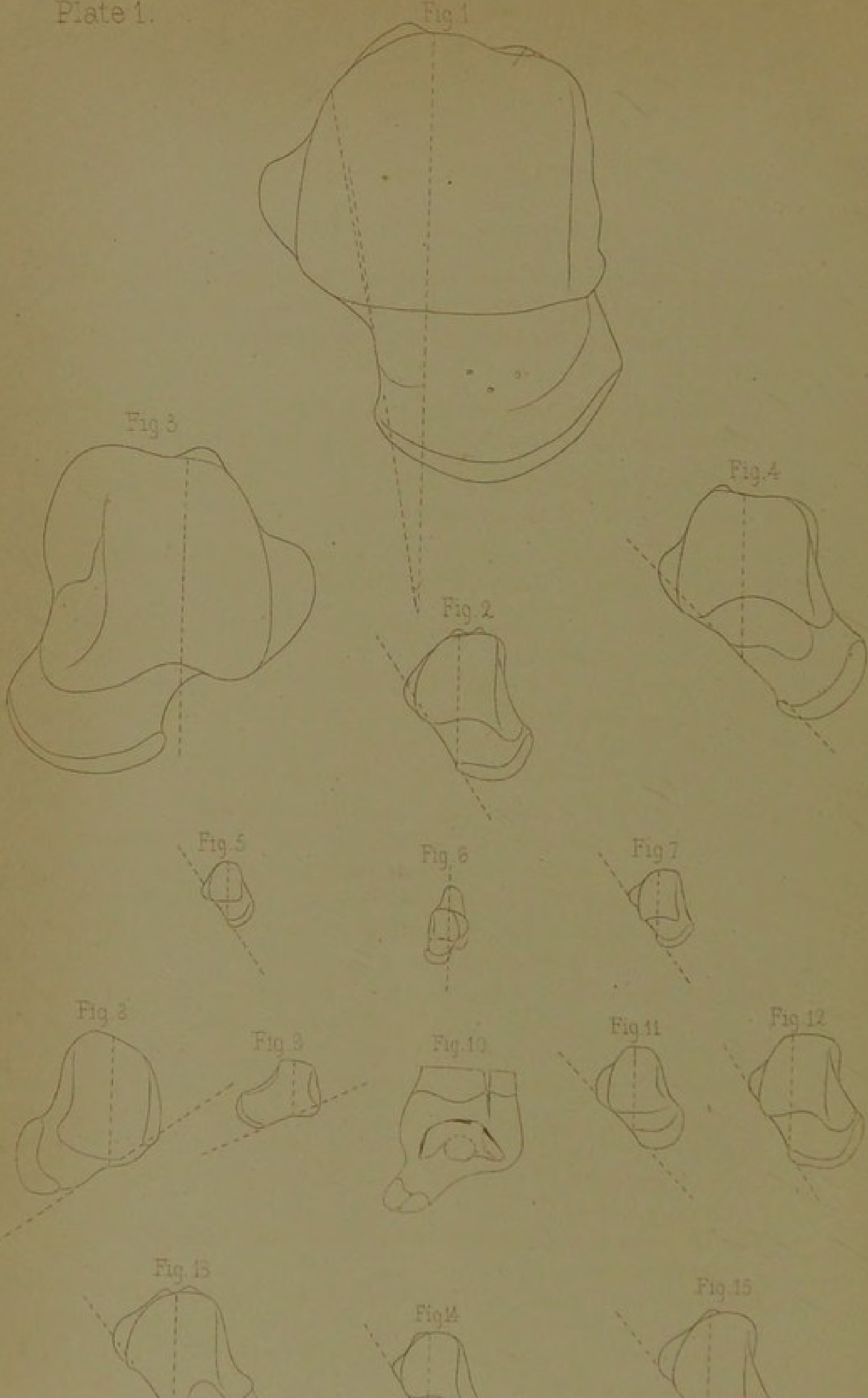
CONCLUSIONS.

We think, therefore, that of all the explanations of club-foot hitherto offered, a mechanical one is the most reliable and satisfactory for the great majority of cases. The histological integrity of the nerve-centres and of the parts concerned, as demonstrated *post-mortem*, in some cases which have died from accidental causes, and the possibility of completely restoring the normal function and position of the deformed limb are facts opposed to a nerve origin or a developmental error in the limb.

Calcaneus, we hold to be an exaggeration by environment of the position natural to the foetal feet during the later period of intra-uterine life, some limitation of extension-movement being normal at the time of birth.

Varus, we think, results from similar causes, but these commence to act at a much earlier period of intra-uterine existence, the great alterations in form of the bones which usually co-exist, and the adhesions at times met with in the ankle-joint, pointing to this. The causes, it may be supposed, commence to act upon the feet whilst they are in the normal position of inversion, and before the capacity for muscular movement in the fœtus is established; continuing to act they maintain this position, and prevent the limb from assuming those positions which are associated with the proper process of further development; the later position being, as before noticed, that of flexion (Talipes calcaneous)—the earlier, that of inversion (Talipes varus).

Plate 1.



S. G. Shattock del.

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DESCRIPTION OF PLATE I.

From drawings by Mr. Shattock.

FIG. 1.—Drawing of a normal adult astragalus. Sagittal line, running through the middle of the trochlea, intersects the navicular facet. The angle formed at the meeting of this line, with another line running along the outer border of the neck, measures 12°.

FIG. 2.—From a healthy fœtus at term (natural size). The sagittal line does not intersect the navicular facet. The angle of the neck measures 35°.

FIG. 3.—From an adult chimpanzee. The sagittal line falls altogether outside the navicular facet. The angle measures 27°.

FIG. 4.—From a young adult Ourang. The sagittal line falls at some distance outside the navicular facet. The angle measures 45°.

FIGS. 5, 6, and 7.—Normal fœtal astragali. The obliquity of the neck is not appreciably greater than later on.

Fig. 5. Enlarged twice—from a 3½ months' fœtus.

Fig. 6. Astragalus, with navicular and calcaneum in position, enlarged 4 times—from a fœtus of 11 weeks.

Fig. 7. Enlarged twice—from a fœtus of about 16 weeks.

FIGS. 8, 9, 10, 11, and 12.—Astragali. From cases of varus.

Fig. 8. From a child aged 18 months (*vide* Case 1). The angle measures 53°.

Fig. 9. From a 7 months' fœtus (*vide* Case 3). The angle measures 64°.

Fig. 10. From a full term fœtus (*vide* Case 6). The angle measures 56°. Ankle-joint shows adhesions within the joint, between the astragalus and the tibio-fibular junction.

Fig. 11. From a fœtus of between 4 and 5 months, affected with double varus (*vide* also Plate II, fig. 8). The angle measures 44°.

Fig. 12. From a 7 months' fœtus (*vide* Case 2), one-sided varus; the angle of obliquity being unusually small, viz. 31°.

FIGS. 13, 14, and 15.—Astragali from cases of calcaneus of different degrees.

Fig. 13. "Physiological" calcaneus, from a healthy fœtus at term. The trochlear surface is extended unusually forwards on the neck. The angle measures 37°.

Fig. 14. From an undersized 8 months' fœtus (*vide* Case 4). The angle measures 33°.

Fig. 15. From a 7½ months' child, which died on the 18th day after birth with imperforate rectum (*vide* Case 5). The angle measures 39°. The trochlea is continued forwards on the neck as far as the margin of the navicular facet.

DESCRIPTION OF PLATE I.

From drawings by Mr. Shattock.

FIG. 1.—Drawing of a normal adult astragalus. Sagittal line running through the middle of the trochlea, intersects the malleolar facet. The angle formed at the meeting of this line, with another line running along the outer border of the neck, measures 12°.

FIG. 2.—From a healthy foetus at term (natural size). The sagittal line does not intersect the malleolar facet. The angle of the neck measures 35°.

FIG. 3.—From an adult chimpanzee. The sagittal line falls altogether outside the malleolar facet. The angle measures [illegible].

FIG. 4.—From a young adult orang. The sagittal line falls at some distance outside the malleolar facet. The angle measures 45°.

FIGS. 5, 6, and 7.—Normal foetal astragali. The obliquity of the neck is not appreciably greater than later on.

Fig. 5. Enlarged twice—from a 3½ months' foetus.

Fig. 6. Astragalus, with [illegible] and [illegible] portions enlarged 4 times—from a foetus of 11 weeks.

Fig. 7. Enlarged twice—from a foetus of about 10 weeks.

FIGS. 8, 9, 10, 11, and 12.—Astragali.—From cases of varus.

Fig. 8. From a child aged 18 months (vide Case 1). The angle measures [illegible].

Fig. 9. From a 7 months' foetus (vide Case [illegible]). The angle measures [illegible].

Fig. 10. From a full term foetus (vide Case 6). The angle measures [illegible]. [illegible] adhesions inside the joint, between the [illegible] and the tibio-fibular junction.

Fig. 11. From a foetus of between 4 and 5 months, affected with double varus (vide also Plate II, fig. 5). The angle measures 41°.

Fig. 12. From a 7 months' foetus (vide Case 7; [illegible] varus); the angle of obliquity being unusually small, viz. 30°.

FIGS. 13, 14, and 15.—Astragali, from cases of [illegible] of different [illegible].

Fig. 13. "Physiological" valgus, from a healthy foetus at term. The trochlear surface is extended unusually forwards on the neck. The angle measures 30°.

Fig. 14. From an undeveloped 8 months' foetus (vide Case 8). The angle measures 30°.

Fig. 15. From a 1½ months' child, which died on the 13th day after birth, with [illegible] (vide Case 9). The angle measures 34°. The trochlea is continued forwards on the neck as far as the margin of the articular facet.

Plate 2.

Fig. 1

Fig. 2

Fig. 3.

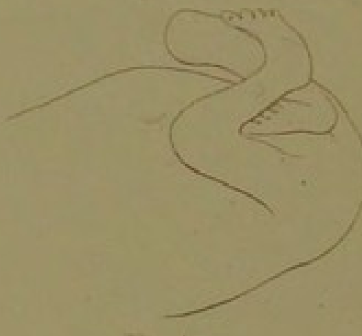

Fig. 4

Fig. 5

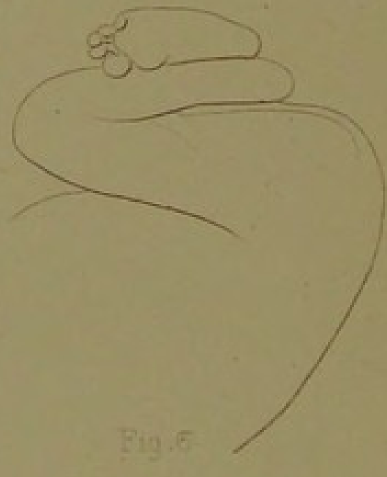

Fig. 6

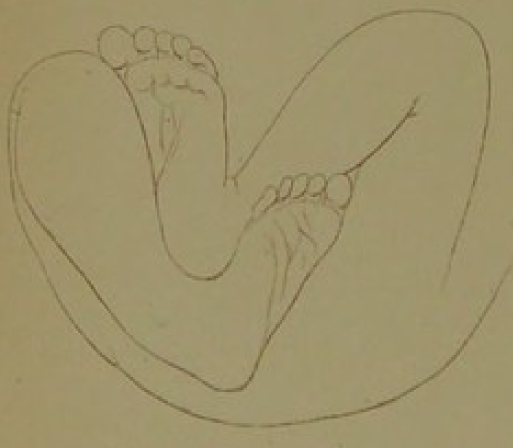

Fig. 7

Fig. 8

DESCRIPTION OF PLATE II.

From drawings by Mr. Shattock.

FIG. 1.—A fœtus, of about 4—5 weeks, showing the feet in the normal position of inversion. From St. Bartholomew's Hospital Museum, No. 1205.

FIG. 2.—A similar specimen, rather more advanced. From St. Thomas's Hospital Museum, No. 1348.

FIG. 3.—Fœtus of about 11 weeks, showing production of calcaneus from exceptional meeting of the feet. From St. Mary's Hospital Museum, North Collection. $\mathrm{M}^{\mathrm{C}}_{11}$.

FIG. 4.—Fœtus, slightly enlarged, of 11—12 weeks with feet crossed, showing normal inversion of the free or crossing foot; the other being semi-flexed, and lying protected in the opposite ham. St. Mary's Hospital Museum, North Collection. No. 11.

FIGS. 5 and 6.—Fœtus of about 5 months, showing normal semi-flexed position of the feet. (Fig. 5, right foot; Fig. 6, left foot.) St. Mary's Hospital Museum. $\mathrm{M}^{\mathrm{C}}_{38}$.

FIG. 7.—Fœtus of about 7 months in uterus, showing normal position of the feet. St. Mary's Hospital Museum. (Reduced in size.)

FIG. 8.—Fœtus of about 5 months, with double varus. The feet bear evidence of pressure, the two outer toes of the left foot being displaced across the roots of the others. (*Vide* also Plate I, fig. 2.)