THE
DUBLIN JOURNAL

OF
MEDICAL SCIENCE,
1 NOVEMBER, 1841.

PART I.
ORIGINAL COMMUNICATIONS.

ART. VI.—*Treatise on the Anatomical Varieties of Congenital Club-Foot, considered in Relation to Convulsive Muscular Retraction.* By Dr. JULES GUERIN, Directeur de l'Institut Orthopedique de la Muette, Chargé de Service Special des Difformités à l'Hôpital des Enfants Malades, Paris.

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I HAVE sought to establish in my treatise on the general etiology of congenital club-foot,* that this deformity, is the result of convulsive muscular retraction. I have assumed as a consequence of this principle, that the different anatomical varieties of club-foot are the result and visible proofs of muscular retraction, occurring in such and such muscles, and consequently the varied manifestations of this single cause. This treatise shall be devoted to the development and demonstration of this proposition.

Four anatomical varieties of congenital club-foot have been described up to the present period, viz. : the pes equinus, varus,

* Published in the last No. of this Journal.

valgus, and talus. These four primitive forms are besides susceptible of combination with one another, and of producing by their combination secondary varieties and associations. If the etiological theory of muscular retraction be true, it ought to account for the formation, not only of each of these varieties of club-foot considered in general, but moreover, of the various elements of which each of them is composed, and of the characters peculiar to it; besides this, it ought to throw light on the other peculiarities and accidents of form which have not been heretofore recognized, showing them to arise spontaneously from a rigorously founded etiology, exercising itself beyond the domain of empirical observation. The morbid forms are really better determined by an intimate acquaintance with the causes, and these again are better established by a rigorous determination of the forms.

I. PES EQUINUS.

The form characterizing pes equinus consists in a certain degree of permanent extension of the foot on the leg without retroduction, adduction, or abnormal abduction, the patient supporting his weight on the extremity of the forepart of the foot. The physiological analysis of the movement of the foot, the examination of this variety of club-foot in its elements, progress, different degrees, diverse transformations, and proper anatomical characters, points out equally that it is the result of muscular retraction. I can also assert, that the same method of verification can be applied to all varieties of club-foot; their common origin is found in the physiological analysis of the movements of the foot, of which they are but the permanent forms, in the examination of each of them, in the constituent elements, in different stages and degrees of its development, and in the consideration of the proximate characters of retracted muscles.

Well, what occurs in the most simple form of equine club-foot? extension of the foot on the leg: that is to say, the per-

manent state of that motion in which the muscles of the calf contract and shorten themselves, and raise the calcis, so as to draw it as near as possible to their superior point of insertion. This is evidently the expression of a physiological movement caused by permanent shortening of the muscles, producing precisely the same appearance as when temporarily shortened. This we set down as our first fact. But pes equinus is seldom simple, that is to say, confined simply to extension of the foot upon the leg. It is almost always compound, that is to say, including other elements common to it, with the greater number of the varieties of the same deformity, the collection of which ought to be explained by the same etiology. Thus I have pointed out among the general characters of club-foot the shortening, broadening and vaulting of the foot; these characters are no where so well marked as in compound pes equinus, so that in some cases they exist when the retraction in the muscles of the calf is hardly, if at all apparent. I have given cases of double club-foot, in which the first and principal element of equinism was wanting on one side, although the shortening, thickening, and arching of the foot, and the turning back and distancing of the toes were as marked as in the other foot, which presented, besides the reunion of these characters, a very marked elevation of the heel. Let us follow the different elements of the pes equinus in their different stages and degrees of development.

In the first stage of compound pes equinus, there is only at first a slight defect in the length of the muscles forming the tendo Achillis. When at rest, the foot forms a right angle with the leg and the heel touches the ground; but the flexion of the foot on the leg can go no farther. The impossibility of this flexion cramps the gait, and renders it difficult; the patient cannot turn on the heel without losing his balance and falling backward. Even at this degree we can recognize the retraction of the solei and gastrocnemii muscles, because being stretched, howsoever great may be the effort made, they will not permit

any movement of flexion beyond a right angle. This first degree of deformity cannot be attributed to the position of the fœtus in the womb, since the foot is articulated at a right angle with the leg, that is to say, it preserves its natural relations. The tension of the muscles of the calf, and the obstacles which they oppose to every motion of flexion of the foot on the leg, point out the real cause of the deformity. In this stage, also, the pes equinus is generally shorter, vaulted, and howsoever young may be the patient, there are two callosities to be seen on the plantar aspect, one corresponding to the heel, the other to the middle part of the fore-foot, each resulting from the habitual pressure of the prominent parts against the ground. Whence do these different circumstances arise? First, the elevation or rather the fixedness of the heel, arises from a certain degree of retraction of the muscles forming the tendo Achillis; secondly, from a certain degree of retraction of the muscles, which pass to the extremity of the foot on its plantar aspect, such as the long and short common flexors of the toes, the flexor pollicis longus, perhaps some of the muscoli accessorii; this accounts for the arching of the foot: for the shortening, there are the dorsal muscles of the foot, the common extensors of the toes, the extensor proprius pollicis. The longitudinal axis of the foot held between these two forces of dorsal and plantar muscles, of which it is the result, cannot elongate itself—whence comes the arching and shortening. Attentive examination of the foot in the living, and dissection in the dead, materially establish this fact. In the living we observe, in the greater number of cases, that the toes are at the same time extended and fixed on the metatarsus; at first elevated on the metatarsal bones, then flexed in such a manner that their free extremities hardly pass the metatarsus, which projects forward almost into the same vertical plane as the latter. I possess examples in which the metatarsus projected even beyond the free extremity of the toes. The cause of this disposition is even better appreciated when we seek to elongate the toes, for we immediately perceive the tendons of

the extensors to project under the skin ; this disposition cannot be attributed to the exercise of walking on the extremity of the foot, for we observe it in the fœtus, and in subjects which can still maintain the foot at a right angle on the leg, and can consequently apply its plantar surface to the ground. It happens besides, as already said, that the retraction does not extend uniformly to all the mnscles, some are more retracted, some less, whilst others of the same class are not retracted at all ; this variety in the degree and result of the action of the cause does not prevent the essential character from appearing less plainly ; moreover, we must say, that the retraction may occupy unequally, simultaneously, or separately all the muscles of the foot ; whence it happens, that there are as many modifications, if not varieties of deformity, as there are combinations in the applications of its cause. In limiting myself to write the history of the admitted varieties of club-foot, I shall not omit to describe the different accidents of form which compose the accompaniments of the principal character of the variety. Thus under this head there are, as I have said before, equine club-feet, with retraction of the muscles of the calf only ; others with retraction of the flexors and extensors ; others with retraction of all the muscles of the foot, but in such degree that the dominant form and characteristic of equinism elevation of the heel continues to be the most apparent symptom of the deformity, in the midst of the different combinations of projections and depressions answering to the different muscles and tendons subjected to muscular retraction.

In proportion to the development of this variety of club-foot, the same elements follow in a parallel manner the same progress. On one side, there is shortening of the muscles of the calf, which increases continually under the influence of the consecutive arrest of development, and which proceeds still elevating the heel more and more ; on the other side, there are the extensor and flexor muscles of the toes, which more and more drag back the toes, and increase the excavation of the plantar surface to such a degree sometimes, as to fold the foot completely on itself

by drawing the forepart of the foot completely under the heel. This forms the most extreme degree of *pes equinus*. Some persons have wished to make of this degree a new variety of club-foot, because they do not understand the connexion which exists between these two stages of the same pathological truth, and because they were not aware that the consecutive arrest of development of retracted muscles is always adding its results to the first effects of immediate retraction. The drawing of the anterior part of the foot under the heel, so that the patient walks on the dorsal surface of the tarsus, is the product of these two successive elements of the same cause, and of the excess of their action on the extensors of the foot, and the flexors of the toes. In a word it is the extreme degree of shortening of the muscles, which in a minor degree of action causes the vaulting of the foot; the dragging back of the anterior part of the foot is but the exaggeration of this vaulting or arching of the foot, i. e. a primitive character of *pes equinus*. This succession of degrees of the same variety is constant; the patients who have been affected with this posterior club-foot, had previously been affected with the ordinary club-foot, and I have been able in some cases to follow the direct transit of club-foot (equine) in excess into posterior club-foot. This transformation cannot be attributed to walking, or to the weight of the body, although to speak truly, its development is in some cases hastened by their influence; the real sufficing cause of posterior *pes equinus* is the retraction of the long and short flexors of the toes. I have been enabled to have direct proof of this from having observed it in the new-born infant. The shortening and the broadening of the foot do not always increase in the same proportion. These characters, in fact, result from an operation less sensible, less exterior, and less active, although evidently intimately combined with the same influences. We may say also that the muscles whose retraction prevents the development of the foot in length, are themselves susceptible of undergoing all the shades, modes, and degrees of retraction, from simple shortening without arrest

of development or manifest paralysis, to extreme shortening, with arrest of development and proportional paralysis. Is it necessary to show that thickening of the foot is a natural consequence of its being shortened and arched? The parts which are obstructed, and, as it were, bridled in their longitudinal development by muscular obstacles, give to the transverse diameter those elements which they cannot add to the longitudinal. There is in this an instance of the law of balance, which acts in much more important and general facts, of which it is scarcely necessary to recall the existence. The inspection of the muscles of the leg and foot in the different degrees of pes equinus, adds new proofs to those already adduced. - From the first stage, the calf is smaller, shorter, and placed higher than in the ordinary condition. These peculiarities are particularly remarkable when the patient is affected with club-foot, only on one side. At the same period we can already feel the edges of the gastrocnemii and solei muscles stretched like hard resisting arrasses, and showing the transition of the muscle into the fibrous state. These characters are so much the more manifest according as they are observed in the more advanced degrees of the deformity, where the heel does not touch the ground up to the time when the foot is entirely confounded in the axis of the limb. Then it becomes impossible to bring back the foot to a right angle with the leg; the calf becomes more and more reduced, flattened, harder and harder, and more elevated, although the entire fleshy elevation has not yet entirely disappeared. The fibrous hardness of its borders, and even of the whole muscles, denotes in certain cases the existence of an almost complete fibrous transformation, arising, as I have shown, from an old and continued tension. This fact of deformity, shortening and fibrous transformation of the calf, on which I have already insisted in my preceding treatise, is too significant to need commentary. It is enough to remark, that in retraction it is the fleshy part which becomes shorter, whilst the tendonous portion

does not participate except in consecutive shortening of the arrest of development ; besides, are not the retraction of the calf, its being drawn up, its shortness and hardness at all times, and at all stages of club-foot, permanent evidences of primitive muscular retraction ? This induction, derived evidently from the simple inspection of external appearances in the living, is more easily proved from the state of the tissues after death. I shall give in another work, a greater number of anatomical observations made on monstrosities, fœtuses, and adults having club-foot in various degrees ; the result from these observations is, that even in the fœtus at the age of five months, the muscles which are the seat of marked retraction, exhibit more or less the characters of fibrous transformation. I have spoken specially of the muscles of the calf, because they are the only ones which can be well appreciated in the living, because they are more exposed to strong traction resulting from the weight of the body on the foot, and are consequently more liable to the conditions of the fibrous transformation. I have always seen in extreme cases this transformation manifested in the generality of the muscles, which play a part amongst the different elements of pes equinus.

Having before us this analysis of each element, each stage, and each degree of pes equinus, it is impossible to mistake the results of retraction, and of the consecutive arrest of development of the muscles.

We shall now apply the same observation to the other varieties of club-foot.

II. PES VARUS.

The essential characteristic of pes varus is the overturning of the foot upon its external surface. We may add directly, that this variety is never simple, and that it is allied in a great majority of cases to a certain degree of equinism. Two sub-varieties result from this alliance ; the equine varus, and varus equinus, (*l'équin varus, et le varus equin,*) according as the form of varus or equinus prevails.

There are then three principal forms of the varus club-foot, varus properly so called, equine varus, and varus equinus.

1. *Varus Simplex*.—Varus properly so called is rare ; I have only observed seven cases in 400 of club-foot. It consists in the overturning of the foot on its external aspect, the plantar surface becoming more or less vertical, and looking more or less internally. This simple form is evidently the permanent representation of a regular motion of the foot, and the result of retraction of the muscles which execute this movement in the physiological state. These muscles are, first, the tibialis anticus, and posticus ; second, the gastrocnemii and flexors of the toes ; any one can assure himself of the justice of these indications, by applying his finger in the course of the tibial muscle, and on the Achilles tendon, whilst the foot is turned upon its external surface. This observation might suffice, but the physiological point which serves as its basis, and which ought to furnish numerous data to the different varieties of varus not having been sufficiently explained hitherto, I shall now dwell a moment on its consideration.

I assert that the turning of the foot on its external aspect, results from the contraction of the anterior and posterior tibial muscles, the muscles of the calf, and the flexors of the toes ; this is established at once by the disposition and direction of the articular surfaces, by the insertion of the muscles, and the direction of their action during the motion of which we speak.

Relative to the articular surfaces it is requisite to note separately the relations of the anterior part of the foot with the astragalus by means of the os scaphoides, with the calcis by means of the os cuboides, and also that of the posterior part of the foot or calcaneum with the astragalus.

Scarpa, following the example of Wenzel, has demonstrated, that in turning the foot on its external surface in this form of club foot, the astragalus does not participate in the inclination of the foot, but remains in its normal position in relation to the malleoli. The truth of this circumstance in a great number of

cases mistaken up to that period, has caused this illustrious anatomist, and all those who have described club-foot after him, to fall into another error. Thus it is not correct to say, that the astragalus does not suffer any displacement, independent of the real turning which it sometimes undergoes, contrary to what Scarpa and all those who have followed him have said; the astragalus undergoes another very remarkable displacement, which consists in a motion of rotation on its vertical axis, by virtue of which its internal surface has a tendency to look forward, and its external surface backward. As it is held locked between the two malleoli, it draws them with it, and causes them to undergo the same displacement, in such a manner that the internal malleolus has a tendency forward, and the external backward. Scarpa saw this displacement of the malleoli, but he only noted it as an appearance resulting from the flexion of the anterior part of the foot inwards. Besides, this displacement is a reality, the existence of which shall be easily established; and what causes it to be mistaken is, that at the same time that the astragalus obeys the motion of rotation which we have mentioned, the scaphoid suffers another in the inverse direction. Whatever it may be, I only wish to note for the moment the relations and directions of the articular surfaces engaged in the twisting of the anterior part of the foot, with the circumstance of the rotation of the astragalus, of which I am about to speak.

The posterior surface of the os scaphoides is circularly excavated to receive the head of the astragalus: these two bones can therefore move upon one another with the greatest facility. But the forepart of the foot is also united to the calcis by means of the os cuboides, and the calceo-cuboidal articular surfaces do not present the appearances of a head received into a cavity, but of two almost plane surfaces in their whole extent, having from within outwards a projection and alternate corresponding depression, which permits of a sliding motion from above downwards and a little obliquity from without inwards;

that is to say, following the circumference of the circle described by the rotation of the os scaphoides on the head of the astragalus. Any one can assure himself of the exactitude of this observation, by the facility with which motions of the anterior part of the foot are produced in this direction on the dead body.

The articular surfaces between the astragalus and calcis present conditions so much more important to note, as they appear to have been hitherto very little remarked.

At first, the articulating surfaces of the calcaneum are neither anterior nor posterior, neither internal nor external in regard to one another, as has been stated by some; but in an intermediate direction oblique from behind forward and from without inwards. The postero-external facette presents a convex surface from without inwards, and from before backwards, and the antero-internal facette a concave surface in the same direction. These two facettes are separated by a broad groove, which gives attachment to ligamentous fasciculi and articular capsules. The corresponding facettes of the astragalus are alternately concave and convex in the same direction. The movements which these surfaces can perform on one another are not and cannot be sliding motions from before backwards, or laterally, as many anatomists following Camper have stated. The motions of these two bones on one another are wonderfully complex, and in the oblique directions which their surfaces enforce. The most extensive motion is that in which the external and posterior portion of the astragalus slides from before backwards, and from without inwards, on the corresponding surface of the calcaneum, at the same time that the anterior and internal portion of the astragalus glides from within outwards, and from before backwards, on the antero-internal surface of the calcaneum, and *vice versa*. The common centre of these two simultaneous movements is nearly in the axis of the limb; and consequently its result is a certain degree of rotation of the astragalus on its vertical axis, which carries its head a little outwards, and causes the subordinate movement of the two

malleoli. An analogous result, but one which ought not be confounded with this, may still be produced, when the astragalus and calcis fixed one upon the other are drawn into a common movement by the deviation inwards of the great tuberosity of the calcis, under the influence of the retraction of certain muscles, which directly flex the foot by its internal edge. In this case even the astragalus has undergone a slight motion of rotation from within outwards, but only in consequence of the simultaneous displacement of the calcis. The head of the astragalus causes, as in cases of essential rotation, a slight projection on the outer side of the foot. Scarpa did not recognize these two kinds of rotation of the astragalus, the one essential, the other subordinate to the primitive rotation of the calcis; because he did not suspect the diversity of causes which originate these displacements, and this caused him to think that the external displacement of the head of the astragalus was always the effect of its being laid bare by the gliding inwards of the scaphoid.* In proof of the reality of the facts which I oppose to an authority so great as that of Scarpa, and without prejudice to those other facts which shall in the course of this treatise reproduce them before the reader, I shall cite the material alterations which are observed in the articulations of the astragalus and calcis of subjects affected for a long time with varus club-foot, or varus equinus. The posterior portion of the internal border of the astragalus has been so strongly pushed against the smaller apophysis of the calcis, that the latter becomes deformed, depressed, and pushed backward, and sometimes almost completely effaced; the posterior part of the astragalus having been a long time applied, and as if crushed against the edge formed by the projecting angle, which rests on the smaller process of the calcis, is thinned and sometimes half detached from

* " Cette preminence, dit Scarpa, ne depend point d'un mauvaise position de la surface articulaire de l'astragale, mais de la torsion vicieuse de l'os naviculaire, qui laisse dcouvert l'articulation de l'astragale."

the rest of the bone, I have specimens in which this alteration is strongly marked.

Besides this motion of rotation of the astragalus, and of simultaneous rotation of the astragalus and calcis accompanying the twisting of the foot on its external side, the corresponding surfaces of the astragalus and calcis permit moreover to the latter a certain degree of rotation on its longitudinal axis, in consequence of its gliding obliquely from before backwards and from without inwards on the inferior facettes of the astragalus. The determination of these motions, deduced solely from the directions and relations of the articular surfaces, becomes better established according as the results furnished by the examination of the insertions, the directions and the mode of action of the muscular powers becomes more clear.

The tibialis anticus commences at the superior and external extremity of the tibia, crosses the limb, and passes to the inferior surface of the first cuneiform bone. In virtue of this direction it acts in two ways; it causes the scaphoid to turn on the head of the astragalus, on account of being inserted anterior to it; moreover, in pulling obliquely from before backwards and from within outwards, it acts on the anterior extremity of the astragalus with an obliquely applied force, the perpendicular resultant of which acts in such a manner as to push the head of the astragalus from within outwards, that is to say, to cause its rotation on its vertical axis.

The tibialis posticus, one of whose inferior insertions is at the tuberosity of the scaphoid, and the other at the cuneiform bones, concurs also in this double movement, whether directly in drawing the tuberosity of the scaphoid upwards and inwards, or indirectly in favouring the action of the tibialis anticus, in order to produce deviation of the head of the astragalus, or finally in determining the adduction of the anterior part of the foot, which increases the intensity of the action of the tibialis anticus by a greater separation of its points of insertion.

On its side, the calcaneum forced to describe with the astral-

galus a slight movement of rotation on its vertical axis, has a tendency also to incline itself on account of the direction of the astragalo-calcanean articular facettes, and of its subordination to the motions of the anterior part of the foot through the medium of the cuboid. From this results, that the longitudinal axis of the muscles of the calf ceasing to run parallel to that of the leg and forming with it an acute angle, is thence placed in a direction favourable to the more complete returning of the entire foot. It is thus that the direction of the action of the muscles of the calf, modified by the first degree of turning of the foot, increases and completes the turning. We may add, that the common flexors of the toes and the flexor pollicis proprius become themselves, under the influence of this displacement, secondary agents in turning the foot, whether they act as abductors or as rotators outwards. In the formation of the varus club-foot the same thing occurs, but in a permanent manner, and often in more strongly marked degrees.

Any one may assure himself that this is the case, by pressing the muscles of which we speak, whilst endeavours are made to bring back the foot to its proper position. The tendons of the tibialis anticus and posticus are hard, tense, resisting, and opposing themselves directly to the restoration of the foot. The tension of the Achilles tendon is little marked in simple varus; it may even be but the result of passive retraction of the gastrocnemii, whose points of insertion have been brought and maintained nearer than usual; but this tension increases in proportion as the state approaches nearer and nearer to the forms of equine varus or varus equinus. If it be the tibialis anticus, its retraction is easy enough to be seen by the way its tendon stands out under the skin. Sometimes, when efforts at reduction are made to render this prominence of the tendon more remarkable, it happens that the tendon presses immediately on the subjacent parts, principally in young subjects, and can no longer be distinguished from those parts. In these cases the deformity is ordinarily more marked, but the spontaneous mo-

tions of the child temporarily increase it, under the influence of the contraction of muscles already contracted. Thence we may follow with the increase of prominence of the tendon of the *tibialis anticus* under the skin, the proportional increase of turning up of the foot.

But this turning of the foot on its external edge is only one of the elements of *varus* in its most complete state of simplicity. It almost always presents two other elements of deformity, viz., permanent adduction and curvature of the foot along its internal edge. The first of these is the result of retraction of the *tibialis posticus*, to whose action it is necessary to add secondarily that of the flexor muscles of the toes, become adductors by the deviation of the anterior part of the foot inwards. The curvature of the internal edge of the foot, to the degree in which we meet it in simple *varus*, depends at first on the gliding of the scaphoid on the head of the astragalus, and on the rotation of the latter on its vertical axis, a rotation which, as I have said, causes its anterior extremity to diverge externally; and thence the curvature on the internal edge of the foot. But the retraction of the adductor and flexors of the great toe assist powerfully in this curvature, and particularly when it is well marked. We may repeat with regard to these muscles, and the elements of deformity which they produce, the physiological and pathological analysis applied to the elements of twisting in *varus*.

Direct experiment has shown me, that physiological adduction is principally the result of the action of the *tibialis posticus* muscle; during this motion we can feel through the skin, and even see behind the internal malleolus the prominence of the tendon, which is hard, tense, and resistant, as is felt when attempts are made to reduce the *varus*, showing that the deviation inwards of the anterior part of the foot is owing to this muscle in particular. The same examination of the flexor muscles and the adduction of the great toe give a similar result; their tendons project under the skin, and mark plainly, by the close relation which exists between the direction of their action, and that

of the element of deformity over which they preside, that is to say, the curvature of the foot along its internal edge; they mark, I say, in a clear manner the influence which they exercise on the development of this element of varus. Before proceeding further, I feel that it is necessary to shew the exact value of the fact of the muscles being shortened in the direction of deformities of the skeleton. I have often mentioned in this treatise, and shall have occasion to mention again the tension of the muscles and the projection of their tendons under the skin, as a proof after many others of their primitive retraction. Since I have established that the bringing nearer of the opposed points of insertion of muscles causes a retraction or passive shortening of their fibres proportional to the sum of the reduction of their course, I have furnished a new argument to those who still support the doctrine of secondary shortening of the muscles in club-foot. But on looking at it more closely, we see that this argument is but specious. And first, without being obliged to recall the direct proofs furnished in my former treatise, in order to establish the fact of primitive muscular retraction, it shall suffice me to show, that if the shortening of the muscles occurred after the deformity of the skeleton, it will be impossible to comprehend why those muscles, passively shortened which ought to be relaxed, are on the contrary tense and prominent under the skin. They ought to do as their antagonists, and above all in children who have not walked. However the contrary always occurs, that is to say, independent of the shortening, there is tension and a marked prominence under the skin, there is hardness and resistance of the tendons; whilst on the opposite side, where the muscles ought to be more stretched and resisting, in consequence of their points of insertion being more distant, they in general preserve their normal condition. This fact is very remarkable in chronic cases of wry-neck, I have shown very often, that the sterno-mastoid portion (sternal portion of authors) is alone primitively retracted, and the cleido-mastoid, or clavicular portion, is only secondarily or passively

retracted. In this double example of the two kinds of retraction, the prominence and hardness of one of the muscles, the depression and softness of the other, explain well the nature and different origin of their shortening.

2. *Equine Varus*.—This is the sub-variety of club foot in which the heel is elevated, and the most anterior part of the front of the foot more or less twisted, but in a degree less than the elevation of the heel.

In the first stage of equine varus the heel is raised, the sole of the foot forming an angle of forty-five to fifty degrees. The foot is not yet turned upon its external surface. Adduction of the foot alone accompanies the elevation of the heel. The patient rests upon the anterior part of the plantar surface of the metatarsus and toes, but principally on their external half. The depression of these parts goes on diminishing from the little towards the great toe, which latter does not touch the ground, or only touches it by some points of its external surface. A vertical line passing by the limb and the tibio-tarsal articulation falls on the little toe in such a manner, that the centre of gravity represented by this line acts in an angle favourable to the increase of adduction of the anterior part of the foot, and consequently favourable to its turning on its external surface. Sometimes one of the toes, principally the great toe, is flexed; but this is an exception to the general rule. This peculiarity is not clearly appreciable, except in infants who have not yet walked. These are the most simple forms of the first stage of equine varus. These forms appear to be exclusively determined by retraction of the muscles of the calf and the tibialis posticus, to which must be added in some cases the exceptional action of one of the flexors.

In the second stage of equine varus, the forms of preceding stages become more developed, and complicated with the following; to elevation of the heel and adduction of the anterior part of the foot, is added excavation of the plantar surface, and internal edge of the foot. In young subjects who have

not yet walked, the surface is traversed by one or two grooves, the first passing transversely along the sole of the foot at the end of the articulation of the first and second range of tarsal bones ; the second in form of an arch, directs itself from the internal border of the foot obliquely to the base of the second toe, and thus indicates the seat of the retraction of the common flexors of the toes, existing simultaneously with that of the flexor pollicis proprius, but separate and distinct from this latter. In the patient which has walked, the toes, with the exception of the great toe, are subluxated forwards on the metatarsal bones. The great toe is ordinarily carried a little forward, but always inclines inwards ; sometimes it participates in the subluxation of the other toes, although in all cases it is less depressed against the ground than the other toes, on account of the adduction of the anterior part of the foot. In these different cases, the excavation of the plantar arch, and of the internal edge of the foot, is obliquely traversed by a fleshy elevation passing from the heel to the base of the great toe, but only in subjects which have walked. Sometimes in the same stage, the three or four last toes are bent under the plantar arch, and the patient begins to walk on the anterior fourth or fifth of the external surface of the foot. There are cases when the contrary takes place, when the patient walks on the anterior fourth or fifth of the external part of the foot, but also on the plantar surface of the last metatarsal bones, and lesser toes ; in this case, the toes corresponding are completely subluxated forward on the heads of the metatarsal bones. In all cases, the characteristic forms of this second stage of equine varus are, the participation of retraction in the flexors and extensors of the toes, with that of the muscles of the calf, and the tibialis posticus. The excavation of the plantar surface, and of the internal edge of the foot in subjects who have walked, and the grooves which traverse this surface in young infants, can have no other origin. We may add, that even in very young subjects, the plantar excavation may take the place of these grooves ; this happens when retraction occurs

simultaneously in all the extensors and flexors. With regard to the fleshy prominence which obliquely traverses the plantar surface of the heel to the great toe, it is sometimes the result of retraction of the adductor, and of the flexor proprius pollicis, sometimes a simultaneous retraction of the plantar aponeurosis, which is gathered into a fasciculus in the joint, and becomes confounded with the muscles previously indicated.

In the third stage the same forms have acquired their greatest development. In the infant which has not walked the external and anterior part of the foot is strongly drawn under the plantar surface; the toes are usually much flexed, or both flexed and extended at once, much separated, and irregularly disposed, as in the third stage of equine varus. What in fact distinguished these two stages from the two different sub-varieties is, that in the equine varus, the heel continues to be much elevated, and is never drawn towards the great toe, the subject only resting secondarily on the external edge of the foot, at the junction of the articulations of the two ranges of tarsal bones, whilst in varus equinus the elevation of the heel is trifling, it is drawn very close to the great toe, and the twisting of the foot on its external, and even its dorsal aspect, is constant. But in both the sub-varieties the excavation of the plantar aspect is extreme; the toes are at once extended and flexed; the anterior part of the foot is dragged under the posterior part, and the leg forms anteriorly at its point of union with the foot, an angle regularly circular, resulting from the subluxation of the astragalus forward, in consequence of the immediate contact acting between the posterior edge of the articular surface of the tibia, and of the superior aspect of the calcis. The third stage of equine varus, in fact, does not differ from the third stage of pes equinus, except in addition of extreme adduction of the anterior part of the foot. In this case, the retraction of the tibialis posticus continues to be carried to its greatest extent, and balances, with the aid of the flexors and extensors of the foot, become adductors by the change of direction of their inferior insertions,

balances, I repeat, the retraction of the muscles of the calf. It is useless to repeat, that with those two principal guides to action which decide the principal forms of this sub-variety of club-foot, there is, or may be, a concurrence of the accessory influences of the small muscles of the plantar and dorsal regions of the foot, in a more or less variable manner. When the retraction is general, and carried to its greatest height, but in different degrees, in all the muscles of the leg and foot, the forms characteristic of each variety of club-foot are accompanied almost always by a crowd of other elements of accessory deformity. It is requisite to keep this circumstance in sight, because it gives at every step the key to secondary combinations, kinds of changes which multiply themselves infinitely around the more fixed, decisive, and marked characters of muscular retraction, which occupies the strongest and most important muscles of the leg and foot.

Varus Equinus.—I have denominated varus equinus, the combination of the two varieties of varus and equinus in such proportion, that the form of varus predominates over that of pes equinus. In this variety of club-foot we must make three stages, and in the first stage there are four principal elements to consider: first, the turning of the foot on its external side; second, the elevation of the heel; third, the adduction of the anterior part of the foot; fourth, the curvature of the foot on its internal edge. We shall see with what facility muscular retraction accounts for each of these elements in their separate stages, by pointing out the muscles which it puts in play.

The analysis which I have given of the primitive varieties, equinus and varus, permits of my omitting an account of many of the developments. It shall suffice to remark, that the muscles whose retraction causes each of those simple forms, associate their action in varus equinus in very nearly equal proportions. I shall note, according to the importance of their action, the anterior and posterior tibials, the gastrocnemii and solei, the common and proper flexors of the toes, the adductor of the

great toes, the peroneus longus, and sometimes the common extensors of the toe, and the extensor proprius of the great toe.

In the first stage of varus equinus, the plantar aspect of the foot forms with the horizon an angle of about forty-five degrees, and the foot rests on the ground on the extremity and length of the fifth metatarsal bone. The heel is separated only by some lines, but the internal aspect of the calcaneum looks upward and forward. In this stage, where the forms are rigorously those which the foot could assume during corresponding physiological movements, it is impossible not to see two evident results, viz. that the relations of the articulations are only repetitions of analogous physiological motions, and that the retracted muscles are those which are affected in these motions. Thus the anterior part of the foot has described a slight motion of rotation on the astragalus, by just so much has the anterior third of the pulley in the astragalus deserted the surface of the tibio-peroneal mortise, and the posterior edge of this latter approaches by a like quantity to the superior and internal surfaces of the calcaneum; with the ideas already laid down, it is hardly necessary to indicate the agents of these dispositions. The tibialis anticus has commenced the turning of the foot, the tibialis posticus has indirectly assisted in this turning, at the same time that it almost alone affects the adduction of the anterior part of the foot: the muscles of the calf have raised the heel, and in consequence of the primitive displacement caused by these muscles, each of them alone, or in union with others, has produced a secondary action, the result of which is added to each element of primitive displacement. Thus the muscles of the calf have aided in the lateral turning of the foot, by means of the inclination first given to the calcaneum by the tibial muscles; the extensors and flexors of the toes, if they have been some time retracted, or if the patient has used the limb for a long time, act as adductors under the influence of the internal displacement caused by the tibialis posticus.

The curvature of the foot on its internal edge is caused, as I

have said already, by the action of the tibial muscles, which indirectly produce a deviation externally of the head of the astragalus, and by the adductor and extensor proprius of the great toe. The common extensors and flexors of the toes aid in the same way, secondarily, by an action derived from the same cause, hence it often results, that the external edge of the foot describes a curve concentric to that of the internal edge, which could not occur if the adductor muscles and flexor pollicis proprius alone exercised their action.

Let us remark on this occasion, that flexure of the foot on its internal edge, infers necessarily deviation of the head of the astragalus outwards, or rotation of the bone on its vertical axis. By this artifice the centre of motion of flexion is transferred towards the calcaneo-cuboid articulation; in the opposite case, that is to say, in cases where the centre of motion of flexion corresponds to the astragalo-scapoid articulation, flexion could not take place without causing considerable separation between the calcaneum and the cuboid, equal to the arc of a circle having for radius a line passing from the astragalo-scapoid articulation as its centre. Finally, we see, without multiplying details, that the same principles, if not the same agents, differently distributed, are applicable to every stage.

It might be thought that it would be sufficient to state the same analytic formula for the following stages of varus equinus, by adding to each the terms of which the new degree of corresponding action is composed, in the development of the forms under which each of those terms is ranked. It is not altogether thus; in the second and third stage of varus equinus some new agents and new combinations occur in the anatomical forms of the foot, the mechanism of which it is necessary to determine.

In the second stage of varus equinus the plantar surface forms a right angle with the ground, and the patient supports himself completely on the external surface of the foot: this is the limit of this stage. Each of the elements of club-foot advance nearly in the same proportion; the rotation of the forepart of the foot,

elevation of the heel, adduction of the foot, and curvature of its internal edge, are the most manifest. But to these elements of deformity the following are added, the two malleoli are no longer situated, with regard to each other, in the usual plane; the internal becomes more anterior, and the external more posterior; the leg also undergoes a slight degree of rotation on its axis. The curvature of the internal edge often becomes angular, and many irregular osseous projections, formed by the disjuncting and subluxation of the calcaneo-cuboid and astragalo-scaphoidienne articulations, are to be seen on the external surface of the foot. Finally, at the same time that the curvature of the internal edge of the foot assumes the angular form, this edge is often confounded with the plantar surface, which shares in this curvature from within outwards, and sensibly diminishes in breadth. The toes are sometimes strongly drawn inwards or outwards, get astride of one another, and sometimes take different directions, some being flexed and some extended. These peculiarities, which may be met with in all kinds of club-foot, only the better demonstrate their common origin, without preventing the distinction of the forms characteristic of the principal varieties.

The displacement of the two malleoli, the internal being carried forward, the external backward, results from two causes; first, from the rotation of the astragalus on its vertical axis, a rotation which I have already remarked has for its immediate and necessary effect the drawing in the same direction the malleoli, betwixt which the astragalus is locked. The second cause of displacement arises from the powerful tension of the tibialis posticus, which drives before it the inferior extremity of the tibia. We know that the tendon of this muscle is lodged in a groove excavated in the posterior edge of the internal malleolus; that it presses on the extremity of the malleolus, as on a pulley, in order to pass from thence to the tuberosity of the scaphoid; besides we know that the superior insertion of the tibialis posticus takes place on the posterior surface of the superior third

of the tibia, near to its external edge, that is to say, in a plane totally different from its inferior insertion. Thus, when there is a considerable degree of retraction, the reflected tendon endeavours to place itself in a right line between the two points of insertion, and to place its two insertions in the same plane, whence the displacement forward of the internal malleolus. Some one might object, that the displacement of the malleoli is the result of an effort made by the patient to replace the point of the foot forward. But in the fœtus, where progression has not as yet obscured the results of muscular retraction, I have seen the top of the external malleolus brought so close to the scaphoid by means of considerable flexion of the foot along its external edge, and of strong adduction of the anterior part of the foot, and of considerable displacement of the internal malleolus forward, that these two points were only separated from one another by two lines. In such a case the tendon of the tibialis is carried forward out of the groove which it usually occupies: this was partly discovered.

The conversion of the curvature of the internal edge into an angle, and the diminution in breadth of the plantar surface, are the results of retraction of the peroneus longus. This muscle having been reflected on the extremity of the external malleolus, passes in a channel formed in the external and inferior surface of the cuboid bone, where it is retained by a fibrous aponeurosis, and thence passes, forming an obtuse angle, to the base of the first metatarsal bone, and to the adjoining part of the first cuneiform bone. A strong contraction of this muscle can cause the internal and external edges of the foot to approach one another, by drawing the first towards the second, whilst the forepart of the foot is held adducted by the tibialis posticus. This approach of these points cannot be caused, except by the drawing in of the point corresponding to the articulation of the first cuneiform bone with the first metatarsal, at the summit of which is formed the apex of the angle, or of the curve formed by the internal edge of the foot. We can see in varus equinus,

where this form of deformity is marked, the elevation formed by tension of the long peroneus immediately above the internal malleolus, and made certain by endeavouring to restore the internal edge of the foot, of the existence of retraction carried to a great extent in this muscle.

The projections formed by the calcaneo-cuboid, astragalo-calcanean, and astragalo-scaphoid articulations, are not less easy of explanation. We may commence by saying, that these projections are to be observed as well in those individuals who have never walked as in those who have made use of their feet. They are the result of the deviation of the head of the astragalus outward, and of pressure exercised on the extremities of the parts contained in the curvature of the internal edge and inferior surface of the foot. When the foot is bent in this direction, independent of the rotation of the astragalus, which is the most perceivable displacement, it impels outwards and subluxates the bones of the second range like the coins of an arch, which are pressed upon and crushed in their smaller extremities. This displacement and this projection are still more favoured by the dragging and distancing of the articulations which border on the edge and external surface of the foot, a dragging resulting from the curvature impressed on this edge and surface. It is hardly necessary to add, those projections of the periphery correspond to the depression of the internal edge of the foot and its plantar surface; and, finally, this last series of results proceeds from retraction of the common flexors of the toes, of the flexor pollicis longus and adductor, to which frequently are added the corresponding extensors, so that the resultant of their simultaneous retraction becomes confounded in the cord of the curvatures of the internal border of the foot and the most internal part of the plantar surface.

The third stage of varus equinus exhibits less difference with the second than the second does with the first. In the third stage the plantar surface looks inwards and upwards, and the foot touches the ground only by its dorsal surface. All the

elements of the second stage exist, but proportionately more developed. The overturning of the foot is almost complete, that is to say, it is nearly upside down; adduction is extreme, so that the point of the foot is sometimes turned backwards; the heel continues elevated, and is carried inward so as to approach the toes. I have seen an example in which the great toe and heel actually met.

Finally, as at the same time cause and consequence of the dispositions which precede, the curvature of the internal edge and plantar surface of the foot forms a very acute angle; it is to this collection of extreme deformities that authors have given the name of complete rolling up of the foot. In these rare cases the anterior part of the foot is so drawn upwards and inwards, that its internal edge and plantar surface are applied against the leg. Let any suppose, along with these elements carried to their greatest degree, extreme retraction of the muscles affected in the production of the forms of the second stage, that is to say, of the anterior and posterior tibialis, the gastrocnemii and solei, and the common and proper extensors and flexors of the toes, and the material reason for these results will be evident; this I have had opportunity of examining in many monsters and adults. In the former the muscular retraction and the consecutive arrest of development are often carried to their greatest degree; thus it is not rare to meet amongst them forms of club foot proportioned to these energetic attacks of their essential cause. I shall add, that in these cases the retraction occupies the greater part of the muscles of the leg and foot, and the accessory muscles of the plantar region, as well as those of the dorsal aspect of the foot participate in it, contributing, within the limits of their force, direction, and the degree of retraction with which they are affected, to the accomplishment of the extreme deformities which characterize the last stages of varus equinus. Thus I have seen in certain cases of retraction, the short flexor of the toes, the accessory of the long common flexor, the ob-

lique abductor of the great toe, concurring to realize the extreme forms of varus equinus.

III. OF VALGUS CLUB-FOOT.

In valgus the foot has a tendency to turn up on its internal edge, the plantar surface looking outwards. This variety of club-foot is very rare, because it can only exist under exceptional conditions of muscular retraction ; but for this very reason they are only the more distinct and easy to determine. We shall first specify the forms characteristic of valgus, and then show their immediate relations to the etiology which regulates the other varieties of club-foot.

We must not confound true valgus with that turning up of the foot on its internal edge succeeding displacement or rachitic curvatures of the knees and bones of the leg. In true valgus the skeleton is sound, the bones have their ordinary form, they have only suffered, as in other varieties of club-foot, changes in their articulations. In fact, valgus in its most ordinary form consists in a motion of rotation of the anterior part of the foot on the head of the astragalus, being a permanent form of this borrowed motion, and requiring the same muscular agents to produce it. All cases of valgus which I have had an opportunity of observing, may be referred to three forms, which may constitute three different stages.

In the first stage, the anterior part of the foot, as I have said, has undergone a movement of rotation from within outwards and from below upwards on the head of the astragalus. The surface and external edge of the foot describe with the external anterior part of the leg an angle varying from a right angle to an acute angle of thirty or thirty-five degrees. One or more tense cords are to be seen ordinarily between these two surfaces, projecting under the skin and opposing themselves directly to the restoration of the foot ; these cords are formed by the anterior peroneus and the common extensor of the toes. In a more advanced stage the forepart of the foot is not only ele-

vated externally, but it is more or less forcibly abducted; here retraction of the lateral peronei is united to that of the anterior peroneus and the extensor digitorum communis.

Finally, in the last stage, an extreme one, which I have only met in monsters, the foot is strongly curved on its external edge and forms an acute angle, the summit of which is in the centre of this edge; in certain cases, this curvature accompanies a very considerable elevation of the external aspect of the foot, which may proceed as far as contact with the external surface of the leg. In these cases there is, besides retraction of the anterior long lateral peroneus, retraction of the short tibial peroneus, of the abductor of the little toe, and of the flexor digitorum communis. The first, being attached to the external angle of the posterior extremity of the fifth metatarsal bone, by its extreme retraction, forces this bone to move on the cuboid; the second, being inserted by one of its tendons into the calcis, and thence passing to the external margin of the base of the first phalanx of the little toe, commences the curvature; at the same time the flexor digitorum communis, the direction of which is oblique with regard to each of the metatarsal bones, completes the curvature of the foot along its external edge.

Such are the forms, and such is the mechanism for the production of valgus in its different stages. It is, at first sight, difficult to comprehend how muscles of such small power as the peronei and common extensor of the toes could be capable of producing almost alone permanent states so opposed to those which result from the more powerful and energetic action of the gastrocnemii of the tibial muscles and of the common and proper flexors of the toes, for the natural movement which valgus represents is very limited, and little capable of balancing the movement caused by the antagonist muscles. Something more is therefore necessary to valgus than the direct retraction of the affected muscles; this is paralysis of the muscles whose antagonism would be too great to permit of valgus occurring. Thus any one could assure himself directly in subjects attacked with

pes valgus in a marked degree, that the gastrocnemii, solei, and the tibialis anticus and posticus, with the flexors of the toes, are more or less paralyzed. They have undergone the extreme degree of that nervous affection, the slightest degree of which stops at simple retraction, that is to say, at immediate shortening and consecutive arrest of development. This is seen, not only in the form of the leg and foot, but still more in the want of power, more or less marked, of the latter. The leg is flabby, flat, and without muscular elevations; the foot moves all in one piece alone in the direction of the least paralyzed muscles; it is often passive in whatever direction it is pushed. In other respects its form is not that of ordinary club-foot, where all the bones appear to be bridled between the different retracted muscles; the foot is, on the contrary, elongated without reliefs or projections; its sensibility and heat, much diminished, are in unison with its motion, and the other characteristics preceding. It is not absolutely necessary to establish the species, that all these particulars should be rigorously met together. I have shown it in its most remarkable forms, because it exhibits itself such in certain cases, but I have taken care to state, that the paralysis which always in a greater or less degree accompanies certain muscles in valgus, is proportioned to the direct degree of retraction inherent in the muscles specially affected in the formation of this variety of club-foot. I shall add, not to exclude any fact from the doctrine that I am bringing forward, that the existence of this solitary paralysis in certain muscles would suffice to permit, of the non-retracted antagonist muscles, causing by the absence of all antagonism, the deformity which they produce in a much more marked manner permanent when retraction is superadded. This is true not only in club-foot but in general, and is seen in the history of all articular deformities.

IV. TALUS.

Pes talus is the opposite of pes equinus, that is to say, the heel is depressed and the forepart of the foot elevated. This

variety, like the last, is necessarily rare, because, like it, it demands an exceptional condition of muscular retraction. In fact, in talus the forefoot is raised, and in its extreme degree it is elevated so as to bring it in contact with the anterior part of the leg. In order that the heel should be depressed to this point it is requisite that the posterior muscles, the gastrocnemii and solei, should give way in a degree much exceeding that of their ordinary elongation. Farther on I shall show how this condition is easily reconcileable with the fact of retraction of the muscles specially affected, to the physiological movement which the form talus represents. In fact this form of club-foot, like all the others, is but the permanent representation of a physiological motion : it is the flexion of the foot on the leg rendered permanent, and this state is undoubtedly the product of retraction of the muscles which are employed in producing the similar motion in a natural state. There is no need of any great disclosures in order to demonstrate both of these points. It is sufficient to see an example of talus to be convinced that there is only a gliding of the tibio-fibular mortise on the pulley of the astragalus so as to bring their corresponding edges into contact ; it is even impossible to distinguish by its form the first stage of genuine talus from the temporary position assumed by the foot in physiological flexion. The muscular agents which produce these two forms are the extensors of the great toe, the common extensors of the toes, the tibialis anticus, and anterior peroneus ; in a word, all the muscles which pass from the anterior surface of the leg to the superior surface of the foot. We have direct proof in these two cases : in simple flexion we feel the tendons of the muscles which are contracted ; and in permanent flexion, or talus, we feel the same tendons projecting more and more under the skin, according as the talus is the more marked, and as more violent efforts are made to establish the normal form of the foot. Meanwhile, what is the influence which enables the relatively more feeble muscles of the anterior part of the leg and foot to overcome the resistance of the more powerful mus-

cular masses of the calf? The same as that prevailing in valgus, viz., paralysis of the muscular masses. Here, as in valgus, the form of the calf, the want of resistance in the muscular fibre, which is converted into a fatty cellular tissue, the real elongation of the gastrocnemii muscles beyond their ordinary bounds ; finally, the failure of contractibility, sensibility, and normal heat, leave no doubt as to the state of more or less complete paralysis affecting those muscles, whilst those of the anterior part of the leg are affected with the same nervous affection only to the degree of simple retraction, so as to be extremely shortened with little or no paralysis.

Such are the principal forms hitherto known of club-foot, considered in their relations to the etiology of muscular retraction. I have confined myself in this essay to the examination of these four varieties and their principal combinations, in order to simplify the demonstration I had to give. But since I became acquainted with the truth of their real origin, I have been enabled to discover some other forms entirely new, which have not been included in the divisions admitted by authors. For, as I have said, the more exact knowledge we possess of causes, the more closely are we led to an exact determination of forms. These new varieties shall be better shown in a particular treatise.

V. CONSEQUENCES AND CONCLUSIONS.

The consequences which follow from the etiological analysis which I have given in this treatise are of two orders ; one, establishing in a definite and positive manner, the fact of muscular retraction as the cause of club-foot in all its different states ; the other conducting to a new system of treatment, inasmuch as it applies in a new manner, those agents which have hitherto been employed in an incomplete, empirical, and dogmatic manner. I shall explain myself on those two subjects of consideration.

When in my treatise on the general etiology of congenital

club-foot I established the fact on which depended all the varieties of this deformity, I was only able to invoke, in support of my opinion, the general proofs which it could establish. In order to demonstrate that congenital club-foot is the product of muscular retraction combined with an affection of the nervous centres of the nerves themselves, I adduced numerous examples in which material traces of the disease coincided with the deformity; I showed besides, that in cases where the traces did not exist, and where, for example, retraction had been the product of the affection of a simple nervous branch, that the nature of the deformity might still be revealed by the general characters of club-foot itself.

I established, besides, that independent of those general characters, common to all the varieties of club-foot, there existed for each of them special characters also furnished by the special manifestation of muscular retraction.

The analysis in this treatise has had for its object to give rules to every disposition and combination of retraction of the muscles of the leg and foot. Each variety, each sub-variety, and each of their stages, are, as I have said, different expressions of retraction, diversified in its intensity, in its situation, and in the multiplied relations of the different elements which compose it. What, in fact, can be more significant to determine the essence of retraction and its material existence, than this association in the same club-foot of the natural state, and of the retraction and complete paralysis of certain muscles? What more characteristic than this succession of forms, appearances, projections, and different manner of existing, so well explained by the shortening and paralysis of such and such muscular agents, so exactly in the line of action of these agents, and representing so well in a fixed state, the form of motions which in the normal state they cause in a transitory manner? What more marvellous correspondence can exist, than that of all the forms of club-foot with the different combinations of which the articulations are susceptible in the physiological state. For the fact is now

proved clear as day, that the most extreme degree of club-foot, the most exaggerated and isolated is but the excess of certain normal motions of the joints producing displacement of the bones of the foot, which are dragged beyond their natural relations, by the same muscles which regulate these same relations in the physiological state? What evidence and meaning can be more explicit and material than that which results for each variety of club-foot, from the tension of muscles placed in the concavities of the curvatures, this tension continually augmenting with the stages of the deformity: finally, from the disappearance of all obstacles, to the reduction of the foot on section of the tendons, which confine the extremities of each of its curvatures? This leads to the examination of the therapeutic consequences.

There are few minds which would not spontaneously deduce the practical consequences which these observations include. I have said elsewhere that the therapeutics are only the etiology reversed. Let us reverse muscular retraction, that is, let us destroy it in its different manifestations; let us attack it and cause it to disappear in the different muscles which it occupies, and we shall have all the therapeutics of club-foot. Thus some one for experiment sake cut the tendon Achilles, because it appeared to be a material and principal obstacle to the reduction of the foot; some persons have even accidentally employed the same operation without any other motive, to certain other muscles of the leg; but these were but blind applications, which possessed neither indications for the present, nor consequences or fixed rules for the future. For whilst it is known and specified for each variety of club-foot what may be the number and relations of the retracted muscles; whilst it is known that such and such forms depend on the retraction of such and such muscles, according to their importance and the degree of resistance which they offer to the restoration of the foot, ought that operation, hitherto reserved for the tendon Achilles, to be applied to them. Let us add that the machines employed to complete the surgical treatment ought not to be applied vaguely to restore the shape of the foot;

but should be applied directly to overcome such and such muscles, and consequently to act in a direction diametrically opposed to their retraction. I shall have said all in adding, that experience has fully and frequently confirmed these inductions of etiology. In *pes equinus*, I divided the tendon *Achilles*, and sometimes the *flexor proprius pollicis*; in pure *varus*, I cut the tendons of the anterior and posterior *tibialis*; in equine *varus*, the tendon *Achilles* and the tendon of the *tibialis posticus*; in *varus equinus*, the anterior and posterior *tibialis*, the tendon *Achilles*, the proper extensor and adductor of the great toe, and sometimes the long lateral peroneus; in *valgus*, the anterior and lateral peronei; in *talus*, the *tibialis anticus*, the anterior peroneus and the common extensor; and finally, the plantar aponeurosis and other muscles for other forms, which I shall not speak of here, but which only require applications of the principle shown in this treatise.

Such is the etiological demonstration of each variety of congenital club-foot, considered in relation to muscular retraction. This, which comprehends a new analysis of the dispositions of the articular surfaces of the bones of the foot, of the muscles which displace them, the motions which they execute, and the displacements which they undergo in each variety of club-foot, may be resolved into the following propositions:

1st. All the forms or varieties of congenital club-foot are the result of muscular retraction, the elements of which are differently distributed and combined in the muscles of the leg and foot; the retracted muscles in each variety of club-foot are those whose temporary contraction causes a similar physiological movement; whence it results, that every club-foot is but the permanent exaggeration of the form of a corresponding physiological motion of the foot.

2nd. All the varieties of club-foot are simple or compound; simple, when they are exclusively the result of retraction of the muscles which preside over the special form of the variety; compound, when to retraction of these muscles is joined, but in

different degrees, that of the greater part of the muscles of the foot and leg ; in such a way that the same muscles may be retracted in the different varieties of club-foot, and the varieties of this deformity are as often due to the combination of the degrees of retraction as to its situation.

3rd. The special forms of pes equinus are the product of retraction of the gastrocnemii, solei, and flexors of the toes ; those of varus of that of the anterior and posterior tibialis ; those of valgus of the lateral and anterior peronei ; those of talus of the anterior tibialis, the long extensor of the toes, and the anterior peroneus, with complete or incomplete paralysis of the gastrocnemii and solei. The forms of the varieties of association which result from the combination of these principal varieties amongst themselves are the product of the simultaneous retraction of the same muscles, to which must be added, as accessory or complementary elements of deformity, retraction of the short extensors or flexors of the toes ; of the adduction of the great and little toe and of the plantar aponeurosis ; in a word, of all the muscles of the leg and foot.

4th. The surgical treatment of congenital club-foot ought to comprehend the section of the tendons of those muscles, whose retraction causes the pathological form of the foot ; when the heel is elevated, the tendon Achilles ; when the foot is turned on its external edge, the tibialis anticus ; when on its internal, the anterior peroneus and the whole or part of the extensor of the toes ; for forced adduction of the foot, the tibialis posticus ; for abduction, the peronei laterales ; for curvature of its internal edge, the adductor of the great toe ; for extension or permanent flexion of the toes, the section of the tendons of the corresponding muscles ; and finally, the simultaneous section of the tendons of those muscles, whose simultaneousness of retraction causes the different combinations of form which club-foot presents.

5th. The mechanical or consecutive treatment of club-foot ought to rest on the same data ; that is, we should employ apparatus, the centres of motion of which ought to answer to the

centres of motion of the displaced articulations, and whose efforts should act in a direction exactly opposed to the action of the retracted muscles.

In a treatise shortly to be published, I shall make known in detail the proceedings, by the aid of which I have fulfilled these indications, as well as communicate some practical observations when they have been reduced to practice.

ART. VII.—*Observations on the Application of Mathematics to the Science of Medicine.* By WILLIAM GRIFFIN, M.D., Physician to the County of Limerick Infirmary, and by DANIEL GRIFFIN, M.D., Assistant Physician to the County of Limerick Infirmary, and one of the Medical Attendants in the Limerick Union Workhouse.

It must be confessed, that the science of medicine, whether we consider the length of time it has existed in the world, the high position it has a right to claim in relation to the well-being of mankind, or the rigorous and searching spirit of the present age, stands most undeservedly low in the scale of knowledge. Many subjects have been cultivated with infinitely more ardour than were of infinitely less importance, and even those persons who have devoted themselves with the greatest assiduity to its improvement, have been extremely slow to avail themselves of those methods of investigation, by the use of which other sciences, many of them but of yesterday's growth, have sprung up and pushed onward, and left it at a hopeless distance behind.

If we look to those sciences that we now admire for the stupendous truths they reveal to us, or the brilliancy and beauty of the discoveries they include, we find that they too, like medicine, have had their days of darkness, uncertainty, and error. Astronomy, the purest, the brightest of them, was mixed up and defiled with the vile superstition and cheating spirit of astrology. According to it, if man was born under a particular aspect of the heavens he might contend in vain against his doom, if an