THE ASTRAGALO-CALCANEO-NAVICULAR JOINT.

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THE text-book descriptions of the joints and their connecting ligaments are perhaps more divergent than those of any other system in the body: this statement especially holds good with regard to the tarsal joints. In the case of the joint which forms the subject of this paper, the plan usually adopted is to describe the articular surfaces between the individual bones, to classify the ligaments accordingly, and only incidentally to notice that this, the most important of all the tarsal joints, is one in whose conformation three bones each take a share. This method undoubtedly leads to considerable confusion and often, to my own knowledge, induces misconception in the mind of the student.

Of all the diarthrodial joints the enarthrosis must be regarded as most closely approaching the ideal, on account of the extensive range and infinite variety of movement which such an arrangement allows. Specialisation in the direction of the resulting movement, however, is in most cases the important end which has to be provided for by the moulding of the articular surfaces, and consequently enarthroses are of rare occurrence in the body, the hip-joint being the most suggestive example.

If all the ligaments attached to the astragalus are severed, and the head of this bone removed from its socket, leaving the os calcis and navicularis *in situ*, the resemblance the astragalo-calcaneo-navicular joint presents to the hip-joint is most striking.

(*a*) In both cases a rounded head is received into a deep and extensive socket.

(*b*) In both, the articular surface of the socket is to a large extent cartilage-clad bone, but not entirely, the continuity of the bony surface being interrupted by other structures.

The acetabulum is clothed to a considerable extent by the thin expansion of the ligamentum teres covering the

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fat lodged in the fovea acetabuli and attached to the edges of that depression. The bony contributions to the socket of the astragalo-calcaneo-navicular joint are supplemented by the calcaneo-navicular ligaments.

(*c*) In both, in no position of the joint is the cartilage-clad surface of the rounded head wholly contained within the socket.

In dried specimens of the tarsus the bones are usually fastened together in such a way that the upper edges of the astragalus and navicularis are made to coincide, a condition which never actually occurs during life. A variable extent of the articular surface of the head of the astragalus, even in the position of forcible flexion of the ankle and abduction of the foot, is always above the level of the upper edge of the navicularis; consequently, a certain area of this surface is never in contact with the articular surface of the socket, but is always opposed to the surrounding capsule.

The more important differences between the two joints, as far as their anatomical features are concerned, are as follows:—

In the tarsal joint the osseous surface of the socket is discontinuous (being formed partly by the os calcis, partly by the navicularis), and consists of two parts, capable of a certain though small amount of mutual displacement, leading to variations in the shape and extent of the socket: in the hip-joint, on the other hand, there is no such discontinuity, and the shape and extent of the socket, as far as the osseous surface is concerned, is invariable. This distinction, however, is more apparent than real, as both the capacity and shape of the articular cup of the acetabulum must certainly be subject to variation according to the position and degree of tension of the ligamentum teres, the tension of this ligament influencing, as I shall presently show, the amount of fat lodged in the fovea acetabuli. The articular head of the astragalus more nearly approaches an ellipsoid than a spheroid, and its receptive socket is of a corresponding shape. The astragalo-calcaneo-navicular joint therefore, though resembling the hip-joint in the depth and extent of the receptive socket, must, from the shapes of the articular surfaces, be placed among the condylarthroses.

I beg to call special attention to the foregoing comparison between the astragalo-calcaneo-navicular and hip joints, as there

are certain features in articular mechanism common to the two, but to these I shall refer later, and will first consider the question, whether it is possible to formulate some definite plan on which the description of the ligaments connecting the astralagus, os calcis, and navicularis may be based, instead of burdening the memory with a long list of differently named ligaments, between which there is no apparent relationship.

In dissecting the ligaments about a joint, in order to determine their disposition, it is important to do so from every aspect, and not only to examine them superficially, but also, when possible, to investigate the surface they present to the joint-cavity. Dissection is trammelled by the canon of description to a much greater extent than one is aware. The anatomist is apt to too blindly follow the accepted description and methods of dissection, and thereby, often unconsciously, to fashion the structure dissected to the mould of the description. This, on the face of it, is unscientific. The human frame is to a large extent but clay in the dissector's hands—clay from which many an artificially isolated product can be modelled; and of all structures in the body, the ligaments are the most plastic in this respect.

In all diarthrodial joints the primitive disposition of the connecting ligaments is one of a simple capsule, the fibres of which connect the edges of the articular surfaces in a cylindrical fashion, and tend to pass in as direct a manner as possible from one bone to the other.

The ligaments of the astragalo-calcaneo-navicular joint may be described under two categories: on the one hand, the ligaments which maintain the integrity of the socket by connecting the bony elements together, and completing the socket where these elements are deficient; on the other hand, the ligaments which retain the rounded head of the astragalus within the socket, being attached on the one side to the neck of that bone, on the other to the margin of the socket, these bands constituting the investing capsule. As the socket in this joint is formed partly by the os calcis, partly by the navicularis, the former includes all the bands connecting these two bones together.

A. The Ligaments completing the Socket, *i.e.*, the Calcaneo-navicular Ligaments.

The usual text-book description distinguishes two such ligaments: the inferior or internal, and the superior or external, respectively. This arrangement is to a certain extent artificial, and the names do not at all express the value of the bands which they are intended to designate. A superficial examination would, I own, lead one to be satisfied with these terms, but to fully appreciate the calcaneo-navicular bands, the removal of the cuboid on the outer aspect of the joint must be effected, and this reveals the fact that they form a more or less continuous ligamentous stratum, which occupies no less than four aspects of the joint—external, inferior or plantar, internal, and superior or dorsal (partially), respectively.

This ligamentous stratum may, for the purposes of description, be divided into three parts. The division is to a certain extent a natural one, as the arrangement, extent, and disposition of the fibres of the three parts present certain important differences. The three parts may be termed inferior, external, and supero-internal.

1. *The Inferior Calcaneo-navicular Ligament.*

On the inferior aspect of the os calcis, between the sustentaculum tali and the cuboidal facet, there is a short and usually well-marked groove, continuous by the medium of a notch with the interval which occasionally interrupts the continuity of the anterior of the two articular facets for the astragalus on the upper aspect of the bone. This groove lodges and gives attachment to a thick bundle of fibres, which, passing forwards and spreading out in a fan-shaped manner, is attached to the inferior aspect of the navicularis. This triangular band exhibits a remarkable fasciculation (fig. 1), the diverging bundles of which it is composed being separated by intervals. The most external bundle of this band is the longest and strongest, and is attached to a well-marked tubercle on the navicularis.[1]

[1] This tubercle is a very constant feature on the bone, and sometimes reaches a very considerable size, a navicular bone in the Anatomical Museum at Cambridge being furnished in this situation with a projecting process which is even

The dissection required to expose this ligament is a somewhat deep one, as it lies to a certain extent under cover of the short plantar ligament, and is covered by a comparatively thick layer of fat, from which processes protrude through the afore-mentioned ligamentous intervals into the articular cavity. If the upper

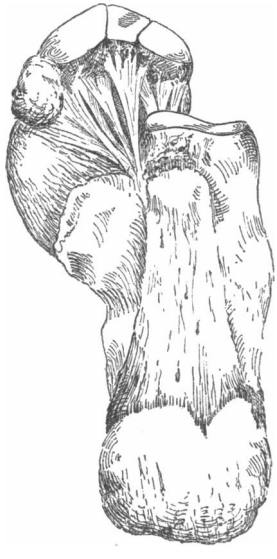


FIG. 1.—The astragalo-calcaneo-navicular joint viewed from below, showing the three parts of the calcaneo-navicular ligament.

(articular) aspect of this ligament is examined, it presents, in the undisturbed state, a somewhat peculiar appearance, this surface being covered by loose fringes of synovial membrane enveloping pellets of fat. A little dissection is necessary to expose the radiating fasciculations of the ligament, and it can then be readily appreciated that these fatty masses are directly continuous with the extra-articular fat through its intervals.

The interpretation of the arrangement of the fibres of this ligament is obvious. The strong thick bundles point to the fact that this ligament is subject to considerable tension, while the fasciculations indicate that this tension is not always equally

more prominent than the internal navicular tubercle, the well-known process giving attachment to the tibialis posticus. As this process receives no mention in the text-books, I propose to call it the *inferior navicular tubercle.*

felt by the ligament as a whole, but that different parts of it are subject to strains of varying intensity at the same time. The significance of the peculiar fatty relations of the ligament will be considered later.

2. *The External Calcaneo-navicular Ligament.*

The fibres of this ligament spring from the narrow rough surface on the os calcis separating the cuboidal from the anterior astragalar facet, this surface widening when traced outwards on to the upper surface of the bone, to which some of the fibres are also attached. The lowest fibres are very short, disposed in parallel fasciculations, with relatively wide intervals between them (figs. 1 and 2); they are separated by a fat-containing interval from the most external band of the inferior calcaneo-navicular ligament. The upper and more superficial fibres are longer and stronger, and do not, as a rule, exhibit fasciculation; they form the greater part of the band, which can be exposed by a superficial dissection in the sinus tarsi. A large extent of this ligament is deeply hidden in the interval between the astragalo-navicular and calcaneo-cuboid joints. Though I have termed this ligament external, yet the fibres are disposed in a somewhat oblique plane, the superficial aspect of the ligament being directed downwards and outwards.

3. *The Supero-internal Calcaneo-navicular Ligament.*

This ligament is inseparable from the inner fibres of the inferior calcaneo-navicular ligament, and consists of a quadrilateral band attached to the whole length of the rough border of the sustentaculum tali. The fibres of this band have a skew disposition: twisting upon itself, the band winds round that part of the head of the astragalus which occupies the interval between the sustentaculum tali and the navicularis, being finally implanted, partially on the inner aspect (tubercle), but mainly on the dorsal aspect of the navicularis. The superficial aspect of this ligament is somewhat difficult to investigate, (1) owing to the close adherence of a thick fascial stratum, in which the tendon of the tibialis posticus is embedded; (2) owing to its intimate connection with the internal lateral ligament of the ankle.

As the tendon of the tibialis posticus crosses the inner aspect of the supero-internal calcaneo-navicular ligament, it traverses a thick fascial stratum, the tissue of which has become condensed to form the walls of a canal transmitting the tendon, the floor of the canal being thickened by a deposition of cartilage. It requires great care to dissect away this fascial stratum, and to remove the deposited cartilage, in order to expose the proper calcaneo-

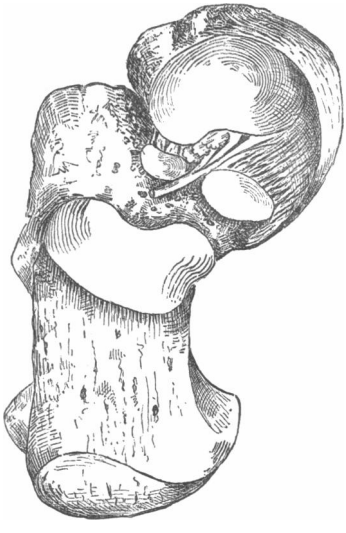


FIG. 2.—The socket of the astragalo-calcaneo-navicular joint viewed from above. Some of the longer and more superficial bands of the external calcaneo-navicular ligament have been removed. In the notch between the anterior astragalar facets on the os calcis is seen the rounded inter-articular ligament, which has been cut in order to remove the astragalus. To the outer side of this band, as it spreads out in the ligamentous floor of the socket, are the synovial fringes covering pellets of fat.

navicular fibres. When the supero-internal calcaneo-navicular ligament is exposed in this way, it is found to consist of closely aggregated parallel fibres, disposed in a continuous non-fasciculated sheet, having a well-defined upper edge in close relation to the astragalo-navicular ligament.

The anterior fibres of the internal lateral ligament of the ankle are usually described as being attached to the calcaneo-navicular ligament, but the mutual relationship between the fibres of the two ligaments is that of an interlacement.

The Internal Lateral Ligament of the Ankle-Joint.—The superficial dissection of this ligament presents the same difficulties as that of the calcaneo-navicular, owing to the close adherence of a fascial stratum which constitutes the sheaths (fibrous) of the flexor tendons—as they wind round the inner ankle into the foot, and the superficial layer of which is known as the internal annular ligament. Posteriorly, however, the distinction between the fibres of the ligament and this fascia may be fairly easily made; and in order to expose the former, the fascial sheet with the embedded tendons should be carefully dissected off from behind forwards. When the ligament is dissected out according to this method, it is obvious that the term 'deltoid' is a misleading one. The internal lateral ligament consists of a quadrilateral mass of vertical, coarsely fasciculated fibres, descending from the tibia to be attached posteriorly to the astragalus, anteriorly to the sustentaculum tali. It is true that the anterior part of this ligament is strengthened by adherent fascia, the forward continuation of which fills up the angular interval between the anterior edge of the internal lateral ligament and the upper edge of the supero-internal calcaneo-navicular

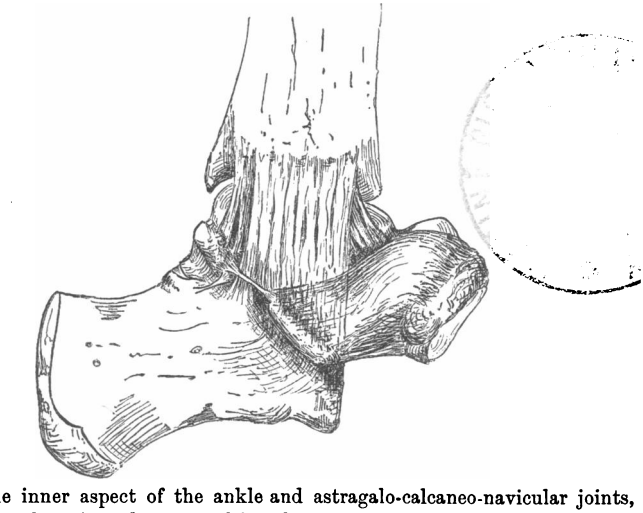


FIG. 3.—The inner aspect of the ankle and astragalo-calcaneo-navicular joints, showing the triangular area of interlacement of the fibres of the internal lateral and supero-internal calcaneo-navicular ligaments above the sustentaculum tali.

ligament (fig. 3), and that this fascia with the ligament may be fashioned into a deltoid arrangement stretching forwards as far as the tuberculum navicularis.[1] I think, however, that this adherent fascia, dense though it is, should be distinguished from the true ligamentous fibres which pass directly into the bone. The connection between the fascia and the ligament is obviously a secondary one, and

[1] Henle distinguishes the anterior part of this sheet as a separable tibio-navicular ligament.

the former must be regarded in the light of an accessory or supplementing structure. With this reservation, the true ligamentous fibres of the internal lateral ligament are limited anteriorly to the sustentaculum tali,[1] and, remarkably enough, are attached to the same extent of bone as the fibres of the supero-internal calcaneo-navicular ligament. In order to achieve this end, and as a kind of compromise between two ligaments, both of which seek attachment to the same bony surface, the vertical fibres of the internal lateral ligament interlace with the upward and forward passing fibres of the calcaneo-navicular ligament. The interlacement of the two sets of fibres may be proved by dissecting and cleaning the fibres of the calcaneo-navicular ligament at the expense of those of the internal lateral ligament, or, conversely. Without making such an arduous and destructive dissection, the interlacement becomes sufficiently obvious when forcible traction is brought to bear on the two ligaments alternately.

There is consequently above the sustentaculum tali a triangular area where the supero-internal calcaneo-navicular ligament is especially thick and strong, as in this situation its fibres are interwoven with those of the internal lateral ligament of the ankle (fig. 3). On examining the outer (articular) aspect of this ligament, it presents a smooth, even appearance where it is in contact with the inner aspect of the head of the astragalus, owing to the thick deposition of cartilage in this situation. This condition is undoubtedly due to the inwardly directed pressure so constantly exerted on this part of the ligament by the head of the astragalus.

Henle describes three ligaments connecting the os calcis and navicularis, but the descriptions of the three bands are placed widely apart in his text-book. He describes a common tibio-calcaneo-navicular ligament (which includes the supero-internal calcaneo-navicular ligament as described above), a lig. calcaneo-naviculare-plantare, and a lig. calcaneo-naviculare dorsale, which can be exposed by a superficial dissection in the sinus tarsi. My thanks are due to Professor Thane for having called my attention to articles by Arbuthnot Lane (*Guy's Hospital Reports*, 1887, p. 254, and the *Journal of Anatomy*, vol. xxii. p. 408), in which he distinguishes in the same way as I have done between an inferior and superior internal calcaneo-scaphoid ligament, and points out that the latter ligament is thickened to resist, with

[1] There is deep stratum of the internal lateral ligament attached exclusively to the astragalus, and the shorter fibres of which are exposed both in front of and behind the longer and more superficial fibres (fig. 3).

the tendon of the tibialis posticus, a tendency to an inward, and not, as is usually described, a downward displacement of the head of the astragalus.

B. The Ligaments constituting the Capsule of the Astragalo-calcaneo-navicular Joint.

These bands, constituting the capsule of this joint, and which serve to retain the head of the astragalus within its socket, may be subdivided into the astragalo-navicular ligaments on the dorsal aspect, and astragalo-calcaneo ligaments on the lateral and posterior aspects of the joint.

The Astragalo-navicular Ligaments.

These ligaments occupy the interval on the dorsal aspect of the joint between the external and supero-internal calcaneo-navicular ligaments. Two such ligaments can be distinguished.

1. *Superficial*, which consists of a broad thin band stretching from the outer and slightly from the upper aspect of the neck of the astragalus, and inclining obliquely outwards and forwards, is attached to the dorsal aspect of the navicularis, some of its fibres being continued on to the middle cuneiform, supplementing the dorsal ligament of the joint between the navicularis and that bone. The most internal fibres meet the upper fibres of the supero-internal calcaneo-navicular ligament at an angle, and are interlaced with them at their attachment on the navicularis. The lower and more external fibres are stronger and thicker, sometimes tending to be fasciculated; the lower edge of this part of the ligament is usually in contact with the upper edge of the external calcaneo-navicular ligament. The whole ligament is very much longer than one would expect from an examination of the dried bones, as, in the first place, it is attached some distance behind the edge of the articular surface of the astragalus;[1] and, in the second place, it crosses that part of the

[1] The following areas may be distinguished in the upper aspect of the neck of the astragalus. In front of the edge limiting the tibial articular surface anteriorly there is a deep smooth groove, marked by vascular foramina, and lodging a pad of fat in the recent state; this groove is bounded anteriorly by a rough linear ridge, which gives attachment to the astragalo-navicular ligament; in front of this ridge, between it and the edge of the articular surface of the head of the astragalus, is a smooth surface, on which the astragalo-navicular ligament rests, without being attached to it.

cartilage-clad surface of the head of the astragalus which always projects to a greater or less extent above the level of the upper edge of the navicularis.

2. *Deep*, which consists of a shorter and less extensive set of fibres, attached to the upper and inner aspects of the neck of the astragalus. The fibres stretch forwards with a slight inclination outwards, and pass on to the navicularis, under cover of the superficial set, whose direction they cross. This ligament is usually to a certain extent under cover of the upper free edge of the supero-internal calcaneo-navicular ligament, the two ligaments being bound together by some loose connective tissue.

The astragalo-navicular ligaments are liable to a good deal of variation. There is sometimes present a third and still deeper set of fibres, which correspond in their direction to the fibres of the superficial set, and which consequently cross the direction of the fibres of the deep set under which they lie.

The Astragalo-calcanean Ligaments.

The ligaments connecting the astragalus and os calcis, and which take part in the formation of the capsule of the astragalo-calcaneo-navicular joint, are three in number:—

1. The external astragalo-calcanean ligament.
2. The internal astragalo-calcanean ligament.
3. The interosseous astragalo-calcanean ligament (partially).

It is concerning these ligaments that there is so much descriptive variance. I have consulted twenty or more text-books, English, French, and German, and there are no two which seem in any way agreed regarding either the nomenclature or disposition of these bands.

To quote a few examples:—In the last edition of *Quain*, the external astragalo-calcanean ligament is described as one in close proximity to, and parallel with, the middle fasciculus of the external lateral ligament of the ankle. Morris and Testut give corresponding names to this band, while it is described by Gegenbaur as the ligamentum talo-calcaneum laterale. Macalister describes the external calcaneo-astragalar ligament as a strong band occupying the sinus tarsi, this band being called by Henle the ligamentum talo-calcaneum laterale, by Gegenbaur the ligamentum talo-calcaneum dorsale, and by Weitbrecht the

ligamentum planum sinus tarsi. Remarkably enough, two such accurate observers as Macalister and Henle omit all mention of the more superficial and posteriorly situated band described in most of the English text-books as the external ligament. At first sight, therefore, it would seem as if in some cases the one, in some cases the other band had been overlooked, but apparently the ligamentum talo-calcaneum laterale of Henle is included by most authors in the comprehensive term 'interosseous ligament,' although Morris, evidently following Barkow, differentiates this band as the anterior interosseous ligament. These are but a few examples; but if the references given by Henle in his *Bandelehre* are consulted, it will be found that the names applied to the ligamentous bands in this region are endless.

I beg to suggest that if one or two points, which may be regarded as the ground-plan for the purposes of description, are kept in view, some sort of order may take the place of this bewildering confusion.

In the first place, it is important to distinguish as far as possible between the bands connecting the bones at the posterior, from those at the anterior astragalo-calcanean articulation, and to describe the latter in conjunction with the astragalo-navicular joint.

Secondly, when giving names to ligaments connecting any two tarsal bones, the name of the proximal bone should always be placed first.

Thirdly, for descriptive purposes, it is convenient to distinguish (as Henle does) between the sinus tarsi and the canalis tarsi. The canalis tarsi is the narrow tunnel towards the inner side of the foot: this tunnel abruptly opens into the extensive fossa of the sinus tarsi on the outer side.

Fourthly, the astragalo-calcanean ligament lodged in the sinus tarsi should (following Henle's nomenclature) be described as an external astragalo-calcanean ligament, as it occupies a lateral position with regard to the anterior astragalo-calcanean joint; while 'interosseous ligament' should be a term reserved for the astragalo-calcanean bands which are lodged for the most part in the canalis tarsi.

With this premise, I may notice here that there are lateral ligaments in connection with both the anterior and the posterior

astragalo-calcanean joints, and that the interosseous ligament is common to the two, constituting the posterior ligament of the one joint, the anterior ligament of the other.

In the posterior joint the *internal lateral ligament* is duplicate: one band passes downwards and forwards from the posterior internal tubercle of the astragalus to the hinder limit of the sustentaculum tali, and bridges over some of the fibres of the internal lateral ligament of the ankle; the other band passes downwards and backwards from the same point on the astragalus to the os calcis behind the sustentaculum tali, and completes the floor of the groove between the astragalus and os calcis lodging the tendon of the flexor longus hallucis; the fibres of this band are closely associated with those of the internal lateral ligament. The *external lateral ligament* is the one to which the term 'external astragalo-calcanean ligament' is usually applied (Quain, Gray, &c.). It is attached to the astragalus just in front of the fibular facet, and, passing downwards and backwards, is attached on the os calcis to the pointed (in well-marked bones) extremity of the tubercle which gives attachment to the middle fasciculus of the external lateral ligament of the ankle, by which it is partially covered. This ligament to a certain extent rides on the astragalus, as below its point of attachment to that bone it is lodged in a narrow groove just in front of the lower part of the fibular facet.

The lateral ligaments of the posterior astragalo-calcanean joint are very obliquely disposed bands, and thereby present a contrast to the nearly vertical lateral ligaments of the anterior joint.

The following descriptions refer to the ligaments of the anterior joint:—

The External Astragalo-calcanean Ligament.

This ligament is very accurately described by Henle. It is a strong band lodged in the sinus tarsi, attached above, to a well-marked tubercle on the inferior aspect of the neck of the astragalus, below, to the upper surface of the os calcis. It is often separated into two parts by a fat-containing interval. It has well-defined edges, the posterior edge being isolated from the interosseous ligament by an interval occupied by a fat-covered pouch of synovial membrane. Its fibres are disposed on a somewhat oblique plane, which meets the plane of the astragalo-calcanean fibres lodged in the canalis tarsi (interosseous ligament) at an angle. The superficial aspect of the ligament is in close relation with the origin of the extensor brevis digitorum, while the deep aspect faces the anterior astragalo-calcanean joint.

The Internal Astragalo-calcanean Ligament.

A deep dissection is required to expose this ligament, as it is under cover of the internal lateral ligament of the ankle and the supero-internal calcaneo-navicular ligament. It consists of a thin and somewhat variable band, attached above, to the surface of the astragalus just below the forepart of the tibial facet, below, to the sustentaculum tali. It is the band to which, I presume, Morris refers under the name 'antero-internal calcaneo-astragaloid ligament.'

The Interosseous Astragalo-calcanean Ligament.

This ligament is usually described as being exceedingly strong and of great thickness, and one has always been led to regard it as one of the most important connecting links in the tarsus. This idea requires some modification. The strongest ligament connecting the astragalus and os calcis is the external astragalo-calcanean (as described above); and if this is cut through, a comparatively inconsiderable force is required to rupture the connecting links between the two bones as far as the interosseous ligament is concerned.

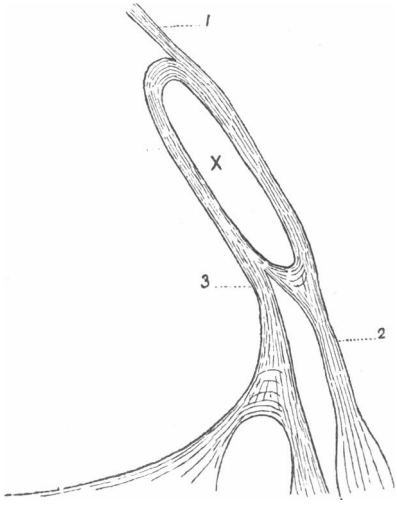
The interosseous ligament for the most part occupies the canalis tarsi; and if the grooves in the astragalus and os calcis, which together complete this canal, be examined, their appearance is certainly against the idea that they give attachment to strong bands. The degree of roughness presented by a bony surface giving attachment to a ligament is to a large extent the index of the strength of that ligament, and these grooves certainly do not exhibit any well-marked roughnesses, but are for the most part smooth surfaces, interrupted by vascular foramina, and lodging a considerable quantity of fat. Further, the canalis tarsi is largely occupied by another and altogether unexpected structure, viz., a deeply-situated contingent of the ligamentum fundiforme.

The ligamentum fundiforme, usually described in connection with the lower division of the anterior annular ligament of the ankle (ligamentum lambdoideum), is the sling-like structure which forms a pulley for the tendons of the extensor longus digitorum and peroneus tertius. This exceedingly well-marked sling has usually but scant attention paid to it in the text-books, and certainly no text-book

description leads to a proper conception of its strength, importance, and disposition. It was first described by Retzius (Müller's *Archiv*, 1841, p. 497), who, finding it in the dog, proved its existence in man; from his investigations it appears to be a very constant structure throughout the mammalia. His description of the deep attachments of the sling are somewhat obscure, and he only casually notices that a certain contingent passes into the "groove of the astragalus"; he mentions, however, that a part of it is attached to the os calcis as far as the sustentaculum tali, and evidently implies that it occupies the canalis tarsi, though he does not use this term. Retzius lays especial stress upon the importance of these deep connections of the ligament, but his description has apparently escaped the attention it deserves, and has not been incorporated in any later writings. I may add that I had worked out the disposition and connections of the ligamentum fundiforme before reading his paper, and practically came to the same conclusions.

The proper method of dissecting out this band is as follows:— The lower part of the anterior annular ligament must be isolated as usual from the rest of the deep fascia with which it is continuous. When this is done, the most strongly marked part of it is a well-defined band which stretches obliquely upwards and inwards across the front of the ankle from the os calcis on the outer side to the lower end of the tibia on the inner side. This band must now be cut through just to the inner side of the extensor longus digitorum, between it and the extensor longus hallucis, and the outer part of the band with the tendons reflected downwards and outwards. It at once becomes apparent that most of the superficial fibres of this (now reflected) band curve in deeply at the inner side of the extensor longus digitorum tendon, and, taking a recurrent course behind the tendons, pass into the sinus tarsi where they are attached to the os calcis, and thus complete a loop, which forms a perfect pulley arrangement for the tendons of the extensor longus digitorum and the peroneus tertius. The free end of the loop—that is, the point where the superficial fibres curve in deeply—is situated on the front of the ankle, and is held in place by three stays derived from thickenings of the fascia, and radiating from it to three bony points in the leg and foot. One passes downwards and inwards to the inner side of the foot, where it becomes continuous with the plantar fascia, though some of its fibres are adherent to the navicularis; a second passes upwards and inwards to the lower end of the tibia; the third passes upwards and outwards to the external malleolus. These three stays together with the ligamentum fundiforme constitute the ligamentum cruciatum (Weitbrecht), or, neglecting the weakest of the three, namely, the one attached to the external malleolus, the more familiar ligamentum lambdoideum. To fully investigate the deep attachments of the ligamentum fundiforme, the astragalus and os calcis must be sawn through in such a way as to expose the whole length of the canalis and sinus tarsi. There is some little difficulty in preventing the structures contained in the canal from being injured by this operation, and the better plan is to saw through the bones in a plane parallel

to, but somewhat behind, the long axis of the canalis tarsi, and then, by the aid of chisel and forceps, to expose the full extent of the canalis and sinus tarsi. The contained structures may now be systematically dissected from behind. By these means the ligamentum fundiforme may be exposed in its whole extent, and its deep attachments investigated (fig. 4). The two limbs forming the loop



Scheme of the fibres of the Ligamentum fundiforme.

1. One of the stays.
2. Superficial or external limb.
3. Deep or internal limb.
× Oval aperture transmitting tendons.

of the ligament may be described as the superficial or external, and the deep or internal, respectively. On the outer side of and below the tendon of the peroneus tertius some of the fibres of the deep limb pass into the superficial limb, or there is an interchange of fibres between the two, and this completes an oval loop, through which the tendons are transmitted (fig. 4). After this interchange of fibres the two limbs may still be distinguished from one another as they arch downwards into the sinus tarsi. The superficial or external limb is a somewhat variable structure, which is widely implanted in the floor of the sinus tarsi. It tends to be coarsely fasciculated, the intervals between the fascicles being occupied by the fibres of origin of the extensor brevis digitorum. The deep or internal limb clings closely to the neck of the astragalus, and passing into the sinus tarsi behind the external astragalo-calcanean ligament, its fibres spread out fanwise, and usually separate into two bands—an outer, which passes vertically downwards and is attached to the floor of the sinus tarsi in close connection with the outer limb; and an inner, which passes nearly horizontally inwards into the canalis tali, where some of its fibres are attached to the astragalus, but the main part are attached to the whole

length of the groove on the os calcis, forming the floor of the canalis tarsi (fig. 4). Between these two bands of the deep limb there is an arched border concave downwards, and bridging over a fat-containing space. Very closely associated with and lying on a plane anterior to that of the deep limb is a ligament, which at its attachment to the os calcis is often blended with its outer band: passing upwards and inwards, it is attached to the groove on the astragalus, forming the roof of the canalis tarsi, and thus tends to cross the inner band of the deep limb obliquely. The disposition of these two obliquely crossing structures has given rise to the misconception of an intermediate part of the interosseous ligament, consisting of two astragalo-calcanean bands crossing each other obliquely, as described by Henle and others; they failed to recognise the connection between these bands and the ligamentum fundiforme.

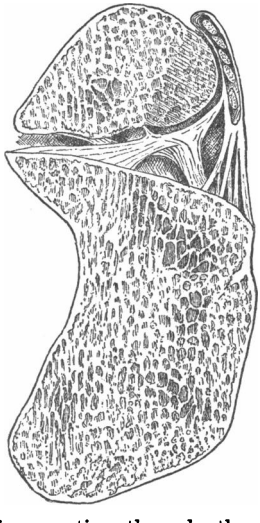


FIG. 4.—A somewhat oblique section through the astragalus and os calcis, showing the arrangement and deep connection of the ligamentum fundiforme.

The above description may be taken as representing the usual disposition of the deep limb of the ligamentum fundiforme. I have dissected it, out in the manner described, in a good many joints, and have found it somewhat variable, both as regards the extent of its connections to the os calcis and astragalus, and the relation it bears to the obliquely disposed astragalo-calcanean ligament. In some cases this ligament tends to traverse the deep limb of the ligamentum fundiforme.

The deep limb of the ligamentum fundiforme, diving into and occupying the whole length of the sinus tarsi, supplies a natural separation between the fibres of the interosseous ligament

belonging to the posterior, from those belonging to the anterior astragalo-calcanean joint, the former lying behind, the latter in front of it. Behind the deep limb of the ligamentum fundiforme in the canalis tarsi there are vertically disposed thin bands, forming the anterior ligament of the posterior joint; when traced outwards, they become scanty, and in the sinus tarsi are usually deficient; in this situation, the synovial membrane of the posterior joint tends to be pouched, and is in direct contact with the fat lodged in the fossa. In front of the ligamentum fundiforme in the canalis there are, in addition to the oblique band already mentioned, some weak and irregularly disposed bands, which form with it the posterior ligament of the anterior joint.

Morestin (*Bull. Soc. Anat. de Paris*, 1894, pp. 1017–1021) points out the deep connections of the ligamentum fundiforme in the canalis tarsi, but he makes no reference to the paper published many years ago by Retzius, to whom the honour of this discovery properly belongs. Morestin comes to the conclusion that the interosseous ligament is "extremely powerful." With this conclusion I entirely disagree: on cutting through all the ligaments connecting the astragalus and os calcis, with the exception of those lodged in the sinus tarsi, I have easily ruptured the remaining ties between the two bones; and were we to include the external astragalo-calcanean ligament, relatively strong though this band is, with the interosseous ligaments, these connecting links between the two bones can in nowise be described as extremely powerful.

The Inter-articular Ligament of the Astragalo-calcaneo-navicular Joint.

In connection with this joint, there is one remarkable band which is very frequently present. Owing to its deep position and the difficulties that lie in the way of its demonstration, its presence, as far as I can gather from consultation of the literature dealing with this joint, has not been previously noted. I discovered it accidentally in demonstrating the socket of the joint: having cut through all the ligaments which I have described in this paper as constituting the capsule, I found that the head of the astragalus was not entirely free, but a band

still connected it with its socket. I have examined a large number of joints, and have found it so frequently present that I cannot but regard it as being a normal constituent of the joint. It is a band which occupies the groove between the two anterior astragalar facets on the os calcis, or a corresponding position when these two facets are confluent, being connected, on the one hand, with the head of the astragalus, on the other, with the ligamentous floor of the socket. It is very variable, and may be present in any one of the following conditions :—

1. A simple fold of synovial membrane reflected into the joint, attached above to the astragalus, and continuous below with the synovial membrane covering the pellets of fat invaginated into the joint between the fascicles of the inferior calcaneo-navicular ligament.

2. An isolated string-like band of synovial membrane, having the same relations to the astragalus and the synovial-covered pellets of fat, and resembling in some respects the ligamentum mucosum of the knee-joint. This condition I have found with confluent anterior astragalar facets.

3. A broad band of synovial membrane, lying isolated within the joint cavity, and having the same connections.

4. A condition resembling 1, in that a projecting fold of synovial membrane is present, but between its layers there are distinct ligamentous fibres connecting the head of the astragalus with the ligamentous floor of the socket.

5. An isolated synovial sheathed ligamentous band, which in some cases is a very well-defined rounded cord attached to the head of the astragalus close to the articular margin, and passing obliquely forwards and inwards in the groove between the two anterior astragalar facets spread out in the floor of the socket, where it is directly continuous with the calcaneo-navicular ligament (fig. 2).

6. In one case, there was a remarkably long band of the external calcaneo-navicular ligament, attached to the posterior exit of a very broad groove between the two anterior astragalar facets, and the ligament connecting the head of the astragalus to the ligamentous floor of the socket passed through the fibres of this band.

The object of this remarkable band is, at first sight, somewhat

obscure. In the first place, I should like to be able to state that this band, when it takes the form of a rounded ligament, is directly responsible for the presence of the groove which occasionally interrupts the articular surface on the os calcis; but, unfortunately, I have found cases where a well-marked groove was present, but there were no signs of a ligament.

The part which this band has to play in the mechanism of the joint is one which, in my opinion, corresponds to that of the ligamentum mucosum in the knee-joint, or the ligamentum teres in the hip-joint. The ligamentum teres, from its weak nature,[1] cannot be regarded as a ligament which is of any service, either in maintaining the relative positions of the femur and acetabulum, or for limiting the movements of the joint: it must, therefore, have some other function to perform. The head of the femur is not the segment of a perfect sphere; and although in certain positions it may be regarded as accurately fitting its socket, yet in other positions this exact correspondence must cease, and a tendency to a vacuum be engendered (thereby seriously interfering with the mobility of the joint), were there not some mechanism whereby the surface and capacity of the socket is made to vary in order to adapt it to the varying curvatures of the head of the femur presented to it. Such a mechanism is supplied by the ligamentum teres[2] and the extensive pad of fat lodged in the fovea acetabuli. The tension of the ligamentum teres varies according to the position of the head of the femur, and the varying tensions of the ligament must influence the fat that underlies it. This fat is directly continuous, through the cotyloid notch, with the extra-articular fat on the inner aspect of the joint, and consequently this affords a means whereby the amount of fat within the joint can vary; that such variations do occur may be directly proved by carefully exposing the extra-articular fat on the inner aspect of the intact joint, and then, if the femur is rotated in different directions, this fat at one time will be found to be sucked in, as it were, through the cotyloid notch, at other times to be protruded

[1] According to Macalister, this ligament ruptures with a stress of about 14 kilos.

[2] I include in the term 'ligamentum teres' the thin expansion covering the fat in the fovea acetabulum, and which is attached to the margins of the fovea. This expansion varies considerably in thickness.

from it. If the fat within the fovea acetabuli varies, the expansion of the ligamentum teres which covers it can also vary, and must be regarded as the variable factor in the socket, whereby the socket is adapted to the varying curvatures of the head of the femur presented to it, this adaptation being to a large extent determined by the movements of the head of the femur to which the ligamentum teres is attached.

In ascribing this function to the ligamentum teres, one difficulty presents itself. According to Krause, the cavity of a joint is invariable (*Der Binnenraume der Gelenke ist unveränderlich*), and by this I presume he means the capacity of the cavity within the limits of the capsular ligament of a joint; consequently, if this capacity is diminished in one direction by the intrusion of fat into the joint, there must be a corresponding increase of capacity in some other direction. This increase of capacity may be provided for by the stretching of the capsular ligament, but this is scarcely likely to be the case in the hip-joint. If the posterior aspect of the capsule of the hip-joint be examined at the back of the neck of the femur, a deficiency in the capsule will be found at the lower and outer border of the zona articularis, and through this deficiency a pouching of the synovial membrane takes place, this pouch of synovial membrane being closely connected with a pad of fat on the inner aspect of the great trochanter. There is therefore in this situation a spot where the extra-articular fat may be either pulled into or pushed away from the joint-cavity through a deficiency in the capsule, a deficiency which may be compared with that on the other side of the joint, bounded by the cotyloid notch and the transverse ligament. Whether, when extra-articular fat is drawn into the joint through the cotyloid notch, there is a corresponding protrusion through the deficiency on the posterior aspect of the joint, and the converse of this, I have not determined, but it is certainly possible.

I have made this long digression on the possible functions of the ligamentum teres as the intra-articular band which I have described in the astragalo-calcaneo-navicular joint may have a somewhat similar function to perform. But little lateral movement is possible at the ankle-joint, the movements of abduction eversion) and adduction (inversion) of the foot taking place

in the sub-astragaloid joints, and in these movements the head of the astragalus rotates within its socket. When the foot is adducted, the head of the astragalus moves, relatively to its socket, in a direction upwards and outwards, a greater extent of the articular surface of the bone making its appearance above the level of the upper edge of the navicularis. Under these circumstances, a smaller amount of the articular surface of the head will occupy the socket, and the socket must undergo a corresponding diminution. This diminution may be effected to a certain extent by an increased pressure of the tendon of the tibialis posticus, the muscle which is chiefly responsible for the movement, on the inner aspect of the supero-internal calcaneo-navicular ligament; but in addition, the inter-articular band which I have described will, when present, have some part to play in bringing about this result. From the disposition of this band (fig. 2) it is obvious that it must be put on the stretch when the foot is inverted, and according to its condition (synovial or ligamentous) it will tend either to pull more fat into the joint through the intervals of the inferior calcaneo-navicular ligament, or to directly elevate and pull outward the ligamentous floor of the socket. There is therefore in this joint a mechanism whereby a variable socket may be constantly adapted to the varying amounts of the rounded head which occupies it, this adaptation being determined, as in the hip-joint, by a band which is attached on the one side to the revolving head, on the other to a factor of the socket capable of variation.

In conclusion, I will summarise the more important points to which I have called attention in this paper. A great confusion exists with regard to the nomenclature and methods of description of the ligaments connecting the astragalus, os calcis, and navicularis, but this confusion disappears by emphasising the fact that there are but two joints between the three bones, and by distinguishing the ligaments of the one joint from those of the other. In the posterior joint, the incomplete capsule is constituted by anterior, posterior, and lateral ligaments; while in the anterior joint, the calcaneo-navicular ligaments are to be described as completing the socket, the capsule retaining the head of the astragalus within the socket being constituted by the astragalo-navicular ligaments on the dorsal aspect, by

external and internal astragalo-calcanean ligaments on the lateral aspects, and by a posterior astragalo-calcanean ligament on the hinder aspect of the joint. Further, in the anterior joint there exists an inter-articular ligament, which, like the ligamentum teres in the hip-joint, serves to adapt the socket to the head of the astragalus in different positions.