THE VARIETIES OF THE OS CALCIS.

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In the paper of the late Professor Pfitzner on tarsal bones the calcaneum is dealt with in a masterly and comprehensive manner, and it is difficult for those who come after him to glean fresh facts from the old ground. The collection at the Cambridge University Museum is, however, larger than that with which any previous anatomist has dealt, numbering upwards of 1000 bones. I have selected 750 of these, the better-preserved specimens, and have noted a few facts which may serve to supplement the work of the able anatomist whose death is such a loss to science. For convenience of reference I have grouped my notes under the following heads:—

I. Size and General Shape.

The largest bone in our collection measures 94 mm. in extreme length, and 9 per cent. of the others exceed 90 mm. The smallest adult bone measures only 48 mm. Length is here taken as the greatest horizontal measurement fore and aft. This may be exaggerated by a shelf-like projection on the upper border of the facies cuboidea anteriorly, while a ridge along the crista achillea on the posterior margin has the same effect. Neither of these, however, affects the size of the largest of our specimens. Breadth varies from 26 mm. to 53 mm. In the average sized and shaped bone length and breadth are correlated, the breadth being about 56 per cent. of the length. But besides this mean, two divergent types are met with—one of lateral compression, which is exemplified in a specimen whose length is 74 mm. and its breadth 35 mm.; the other of vertical compression, with shortening from before backwards. The best-marked example of this measures 57 mm. long and 50 from side to side.

An index, $\frac{\text{breadth} \times 100}{\text{length}}$, may be formed to express these

relationships, which in the two extreme cases respectively amounts to 47·9 for the specimen of lateral compression and 87·7 for the second extreme, while in typical specimens the average comes between 50 and 60.

In measurement of breadth the sustentaculum tali should theoretically be excluded, as the degree of projection of this is variable, without correlation to the general breadth; but the difficulty of obtaining any other fixed points for breadth-measurement makes its exclusion inexpedient. I have therefore included this in all the above measurements. As an instance of variation in the projection of the sustentaculum, the specimens numbered 513 and 535 gave respectively:—

Length.	Breadth with Sustentaculum.	Breadth without Sustentaculum.
89	43	26
80	41	30

In like manner, measurements of breadth at the posterior extremity across the region of the plantar tubercles possess no advantage, as the relative projection of the tuberculum plantare externum is as variable as that of the sustentaculum.

The height of the bones was found to be much more constant than the breadth, but increases slightly in the cases of lateral compression. The height is as a rule 50 per cent. of the length. In laterally compressed bones it rises beyond this, while again it presents certain slight varieties, without respect to other characters. Thus a bone having an average breadth-index showed a height of 60 per cent. on measurement. This was the greatest proportional height noticed.

II. Components.

The bone is most conveniently, although arbitrarily, divided for the purposes of description into four parts:—

I. *The Corpus.*—Under this division I include all that part of the bone covered superiorly by the facies articularis posterior. This nomenclature is convenient for the purposes of description.

II. *Processus Anterior.*—This includes all that part of the bone directly anterior to the corpus.

III. *Processus Posterior.*—That portion of the bone posterior to the corpus.

IV. *Sustentaculum Tali.*—The lateral projection on the medial upper border of the corpus and processus anterior.

Part I.—The Corpus.

Of the four surfaces presented by this division of the bone the superior is, by definition, coextensive with the facies articularis posterior. The outline of this surface is an irregular pentagon with rounded angles, apex backwards. The plane of the surface is in general disposed with its long diameter directed forwards and outwards, and is curved with a very varying degree of convexity along this line. From side to side it varies from flatness to gentle concavity, or, more rarely, faint convexity. The edges of the facet are very clearly marked, being slightly raised above the surrounding parts, except at the anterior margin, where the surface passes on to the processus anterior almost imperceptibly. The perforations in the floor of the fossa calcanei are the best guide to the margin which forms the boundary of these holes in most cases.

The convexity along the greatest diameter has an average radius of curvature of 30 mm.; but one bone (No. 414a) had a radius of curvature of only 12 mm., while several others had a radius of over 40 mm.

Towards the medial angle of the facet the amount of curvature increases. Towards the lateral border, however, the curve is usually the same as along the middle line of the surface.

The chord of the arc formed by the convex articular surface has nearly constantly an angle of 45° to the horizontal, and does not vary with the amount of curvature of the arc.

Of the five margins of the facies articularis posterior the *anterior* is the shortest. It runs across the central portion of the fossa calcanei, and is sometimes irregular, owing to the vascular perforations along this line, and at other times indistinct, when the perforations are absent.

It varies in (*a*) *Length*, being very rarely absent when the antero-lateral and antero-medial margins meet at an angle.

Specimens of this kind are under 2 per cent. of the whole. From this extreme to an almost straight line running from the external surface of the bone to the facies articularis medialis (see fig. 4) all gradations are found.

(β) *Shape.*—The anterior part of the facet is in a few cases (4 per cent.) extended to the floor of the fossa calcanei in a tongue-like projection. This, when present, is on a different plane from the rest of the facet, which it meets at an angle of about 120° (fig. 2*a*). The marked tongue-like extension of this facet, when present, usually lies over and along the crista lateralis of the processus anterior.

A minor degree of the above variation is more common (about 4½ per cent.) in which a small overflow occurs, giving a rounded appearance to this margin. This partially surrounds a perforation in a few of these cases, giving a broken appearance to the whole surface.

A marked rounded central extension is very rare, one case only being noticed in 750.

The *antero-lateral margin* is also short, and meets the anterior in an obtuse angle. It is directed forwards and inwards, and is usually faintly convex. It flows into the postero-lateral margin, the two uniting in a rounded obtuse angle.

The *postero-lateral margin* is the most prominent part of the bone when viewed in norma lateralis. This angle very rarely approximates to a right angle. Sometimes it is lost, the two margins making parts of a continuous curve, but this is uncommon.

The *postero-medial margin* meets the postero-lateral in a rounded acute angle (*apex*) posteriorly. In front it passes into the antero-medial by a rounded obtuse angle at the root of the sustentaculum. This medial angle is sometimes sharp, and occasionally is extended along the superior surface of the sustentaculum to touch the facies articularis medialis (1½ per cent.), thus occluding the sulcus calcanei posterior. In one case (No. 607) this junction was so extensive that the two articular surfaces were completely confluent (fig. 3).

The fifth or *antero-medial margin* forms the boundary of the sulcus calcanei laterally. It is almost always sharply defined, and meets the anterior in an obtuse angle. In the case quoted above (No. 607) this border was absent. In another

a tongue-like projection ran across the middle part of the sulcus calcanei to the facies articularis medialis, connecting the two surfaces. Along the edge of these two margins the capsular ligament arises, but hardly ever leaves an impress on the bone, as it is very weak.

The postero-lateral and antero-lateral margins are rounded off and sloped downwards in rather more than 1·5 per cent. of cases, so that part of the facet is visible in the norma lateralis. In another ·5 per cent. this facet is well marked (fig. 4). This is due to lateral overgrowth of the lateral tuberosity of the talus downwards, which thus comes to clasp the lateral surface of the corpus at this spot. Just where the postero-lateral margin ends, in what I have previously termed the apex of the pentagon, there is in 3·5 per cent. of cases an added triangular area with its apex backwards and outwards, on a slightly different plane. This is the facet for the os trigonum (see fig. 2). In 5 per cent. more a somewhat less definite triangular area is noticeable.

The Lateral Surface of the Corpus.—This is marked off, superiorly, by the antero- and postero-lateral edges of the facies articularis posterior, and by the lower margin of the bone inferiorly. A line drawn from the extreme hinder end of the articular facet to the narrowest part of the ridge, just in front of the processus lateralis tuberis calcanei, conveniently limits it posteriorly. This arbitrary hinder line is vertical when the bone is placed in position. Another arbitrary line marks out this surface anteriorly. The line is best drawn from the anterior end of the articular facet above to the cuboid tubercle below. The surface thus marked out is irregularly bi-convex, and in our series presents every possible combination of the following five features:—

(i.) *Sulcus Subarticularis.*—This is a shallow groove running immediately below the edge of the facies articularis posterior. It is directed downwards and forwards, and is lost at the anterior extremity of the lateral surface.

This feature may usually be made out, although its depth is exceedingly variable. In the floor of the groove a roughness or small tubercle is met with for the lateral talocalcanean ligament. This may be termed the *tuberculum ligamenti talo-*

calcanei. Its position is very constant, but it may appear larger than usual owing to its fusion with the peroneal spine.

(ii.) The peroneal spine, *Tuberculum ligamenti calcaneo-fibularis.*—This is a small tubercle situated just below the middle point of the sulcus subarticularis. Its variable degree of prominence depends possibly (1) on the spread of ossification into the base of the ligamentum calcaneo-fibularis, but more probably on (2) the strength and varying obliquity of the ligament inserted into it, and the extent of the area to which its fibres are attached.

This tubercle is present in 43 per cent. of cases as a well-defined knob; in some 10 per cent. more it appears only as a roughness. In 4·5 per cent. it is displaced downwards. In 25·5 per cent. it is fused with the tuberculum ligamentum talocalcanei. In 5·5 per cent. it is displaced backwards. In the remainder it is normal, namely, 64·5 per cent.

(iii.) Below the tuberculum ligamenti talocalcanei a groove runs horizontally forwards, and is lost on the general concavity of the lateral surface of the processus anterior. This *sulcus lateralis* anteriorly meets the sulcus infra-articularis at the anterior margin of the lateral surface of the corpus.

The degree of distinctness of this groove depends on the amount of development of the above spine and of the eminentia retrotrochlearis.

(iv.) *Processus Trochlearis.*—This is the most variable feature of this region. In 60 per cent. it is absent, and this surface is comparatively smooth and convex, and passes off by a rounded margin on to the inferior surface of the corpus.

In a very few cases of complete absence of a projecting processus trochlearis two more or less definite smooth peroneal grooves, separated by a very faint ridge, may be seen running obliquely downwards and forwards.

When well developed, the processus trochlearis juts out below the level of the anterior extremity of the facies articularis posterior. When the calcaneum is put into its proper position it lies just below the middle point on the line delimiting the lateral surface anteriorly. It is obliquely disposed, with its long axis directed downwards and forwards.

The trochlear process is present as a very prominent isolated

structure in 20·5 per cent. It is distinct, although less marked, in 16 per cent.

In a specimen chosen as being typical of the largest-sized trochleæ the following features were noticed:—

The process rises from an oval base, 13 mm. long and 6 wide, whose long axis makes an angle of 45° with the horizontal.

The sides are smooth and faintly concave above and below, and meet each other in a rounded ridge some 2 or 3 mm. shorter than the base. The inferior surface of the process is glide-faceted for the tendon of peroneus longus. The superior, though smooth, has no definite facet. This is what one would expect, as the tendon sheath here takes all the strain of the tendon of peroneus brevis. The projection of the structure is 6 mm.

All varieties and sizes of trochleæ are met with intermediate between that just described and the complete absence of the process. These intermediate forms, however, differ very considerably in character, and they fall into three groups:—

(α) Oval form and well isolated. The best-marked group of which the above description holds.

These may be subdivided by size if desired, but this is wholly unnecessary. This group comprises 60 per cent. of the well-marked form.

(β) Ridge forms. Where the whole process is narrowed and lengthened, and ends externally in a sharp ridge.

One specimen of this group measured 19 mm. in length and 5 mm. in height by 1 mm. in breadth. The typical examples of this form usually show a glide-facet superiorly for the peroneus brevis.

This group comprises 40 per cent. of the well-marked form.

(γ) Imperfectly developed forms, where the limits between the trochlea and the retrotrochlear eminence are not clearly defined, a faint groove being the only guide to indicate the separation between the true trochlea and the eminentia retrotrochlearis. A glide-facet for the peroneus longus usually occupies the groove, and in the front of the indistinct swelling another groove may exist for the peroneus brevis (fig. 8).

This form occurs in 6 per cent. of bones.

The distinction between these groups is arbitrary, as among

our specimens we have an unbroken series upwards from the most undefined to those in which the trochlea is completely separate. This will be referred to later.

(v.) Just posterior to the processus trochlearis there is on this surface a large oval eminence, the *eminentia retrotrochlearis*. It is of very variable height and extent, but is nearly always to be made out. Its prominence depends, in all probability, on the disposition of the cancelli which abut on its deep surface internally (see later). From the postero-inferior margin of the eminence a faint rounded ridge passes backwards and downwards to the processus lateralis tuberis calcanei. This ridge is in some cases interrupted by a vertical groove.

Professor Pfitzner regarded the processus trochlearis as the remains of a primarily independent ossicle, which had become incorporated with the general mass of the bone at a later period, and in consequence he termed it *calcaneus accessorius*. His reasons were, briefly put:—

(1) In mammals, even where the peroneus longus is weak, a trochlear process is constant.

(2) In man it bears no relation in point of size to the muscular development, age, sex, or occupation of the individual.

Therefore its presence is not due to the peroneus longus.

(3) But in some of his specimens there were appearances which he believed to be indications of a fused ossicle, and in one, a case of a fourteen-year-old girl, on the right foot he discovered a separate ossicle which was just on the point of fusion with the corpus calcanei. While not laying too much stress on this one case, he regards the sum of the evidence as bearing out the hypothesis that the trochlea is a fused calcaneus accessorius.

In the light of the known inconstancy of epiphysial centres of ossification, it is probable that the evidence in favour of the existence of a separate morphological unit is not as strong as the late Professor Pfitzner considered it to be. On the other hand, there is for this region of the outer side of the calcaneum no additional centre of chondrification in the human embryo, and there is no additional tarsal element known to me in this position in any other animal. The projection of the trochlea is due to the extension first of cartilage and then of bone into the

base of the fibrous sling which at an early period of fœtal life (fifth month) is demonstrable here, and Pfitzner himself has proved that there is no necessary correlation between increased ridging of bones and the development of the muscles attached thereto.

I have seen no condition in our whole collection of over 1000 calcanea indicative of the origin of the trochlea from an independent ossicle, and the occurrence of one case of sporadic epiphysial ossific centre is to be put probably on the same platform as the occasional presence of an epiphysial lamella on the tip of the coronoid process of the ulna and other similar anomalies.

From a study of our specimens, it seems to me that the trochlea is formed by the extension of chondrification and ossification into the base of the attachment of the fibrous sheaths of the peronei tendons where that sheath is attached to the front of the laterally-bulging area of the lateral surface which supports the outer series of ascending pressure-planes of lamellæ to support the upper cuticular surface. This area posteriorly forms the retrotrochlear eminence, and anteriorly is liable to become specialised and moulded by the pressure of the peronei tendons and the tension of their sheath.

In favour of this view we have the following facts:—

(1) A processus trochlearis is always accompanied by an eminentia retrotrochlearis of greater or lesser magnitude.

(2) A series of bones may be taken which show a gradually increasing separation of a trochlea from a single lateral swelling.

(3) Where the eminentia retrotrochlearis has not extended very far forward, a single glide-facet may be seen on its anterior margin for the peroneus longus.

(4) The fact that at this point a sesamoid cartilage or bone is very frequently to be met with in the tendon of peroneus longus, showing that a very considerable pressure is sometimes exerted in this region.

(5) The occasional very large size of the trochlea is due partly to the greater original size of this lateral eminence in the anterior portion of the bone, and to greater extension of cartilage and subsequently of bone on the ridge between the

tendon grooves, stimulated perhaps by the increased pressure of the tendon on the bulging surface of the bone.

The trochlear swelling was found as a slight cartilaginous ridge in one full-time fœtus in our dissecting-room.

The Medial Surface of the Corpus.—This surface is arbitrarily limited by lines similar to those delimiting the lateral surface.

The general contour of this area is concave, with the inferior margin rounded off and flowing continuously into the plantar surface.

The supero-anterior angle is occupied by the sustentaculum, whose varieties will be described later on. The groove for the tendon of flexor longus hallucis, which lies on the under side of the sustentaculum, in a considerable number of specimens extends downwards and grooves the contiguous margin of this surface. The groove is confined to this surface behind the sustentaculum when the tendon touches the bone at this region; it also may be on this surface below and in front of the sustentaculum. Bounding this groove inferiorly there is always a linear roughness which gives attachment to the tendon sheath. Posteriorly ridge and groove fade away, but at a variable distance. Sometimes the tendon indents the bone along the postero-medial border of the upper facet. Below the middle of this line a vascular hole of great constancy is to be seen, into which a branch of the calcanean trunk of the internal plantar artery enters. If absent, several small holes take its place.

In 9 per cent. a distinct curved line, with its concavity directed downwards and forwards, marks the origin of the musculus accessorius, and is continued backwards on the internal surface of the processus posterior. The curved inferior border varies in the degree in which it is rough and lined for the origin of the plantar ligaments. The compact layer of this surface is thicker than is that of the lateral surface.

The Plantar Aspect of the Corpus.—The trigonum plantare is bounded by the inferior margins of the lateral surfaces of the corpus laterally, forming the sides of the triangle and meeting in the cuboid tubercle anteriorly. The tubercle itself is on the arbitrarily separated processus anterior. The base is marked

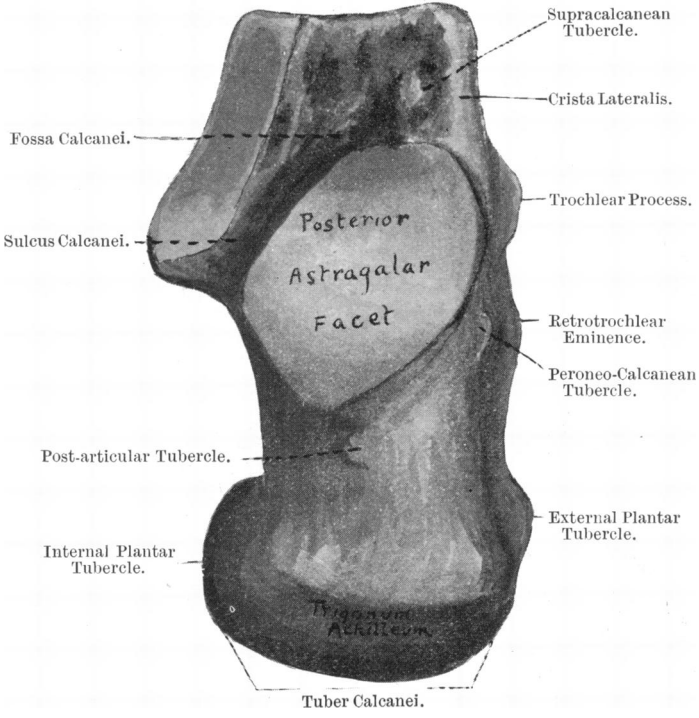

FIG. 1.—Norma verticalis of bone, showing various points seen from this view.

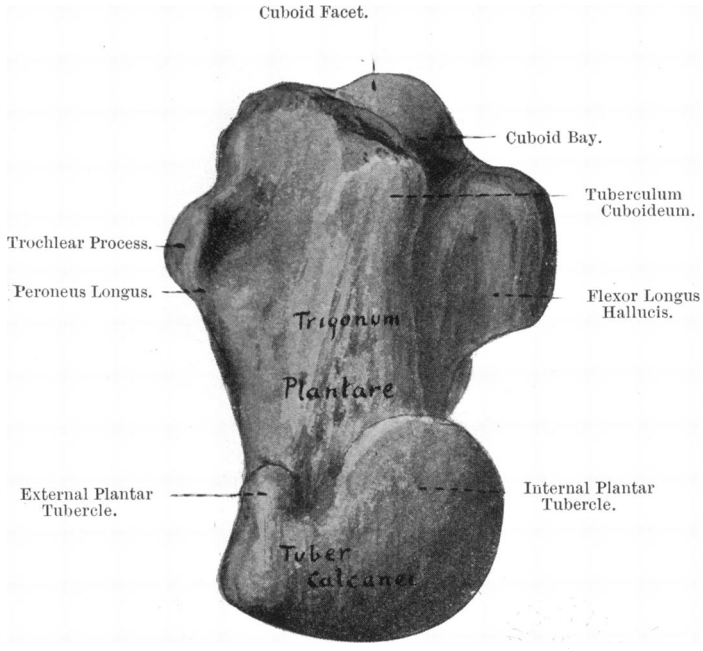

FIG. 1A.

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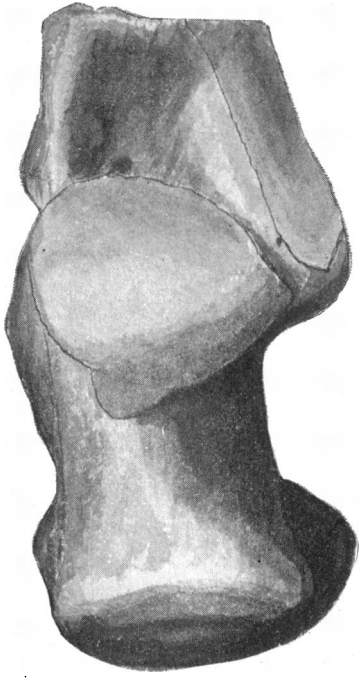

Fig. 2.—Bone 623—Os trigonum facet.

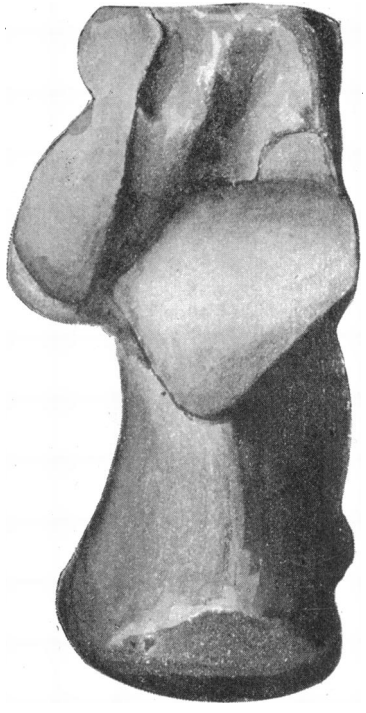

Fig. 2A.—Bone 370—Facet on processus anterior or crista lateralis.

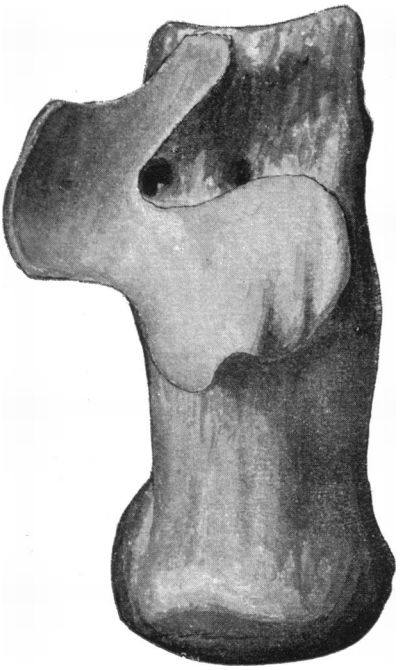

FIG. 3.—Bone 607—Fusion of facies articularis posterior and facies articularis medialis.

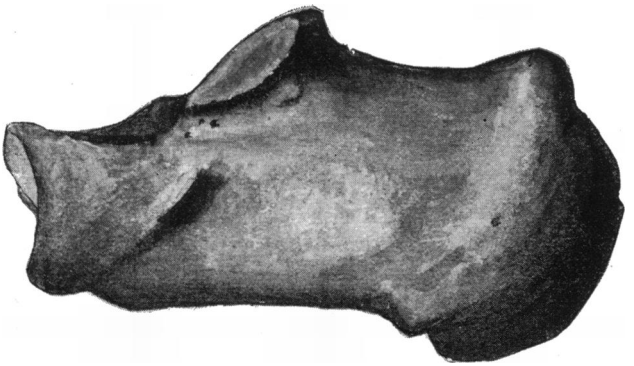

FIG. 4.—Bone 585—Vertical lateral marginal facet for astragalus (tuberosity).

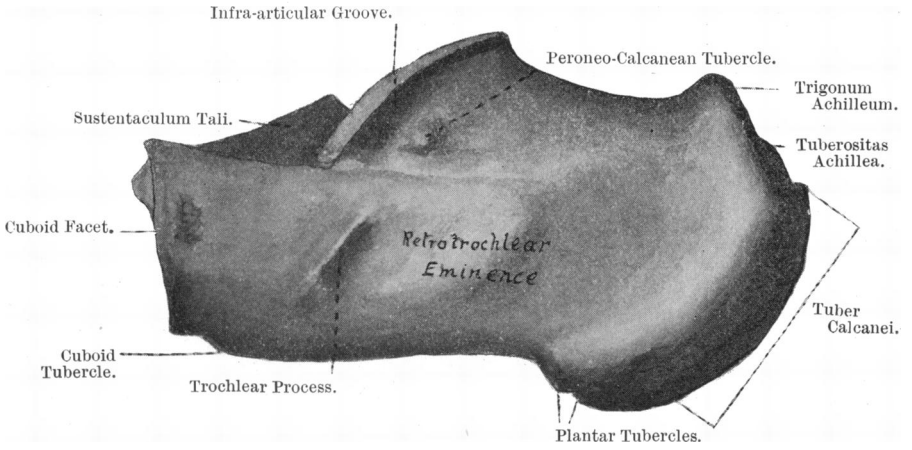

FIG. 5.—Norma lateralis, showing various parts referred to in paper.

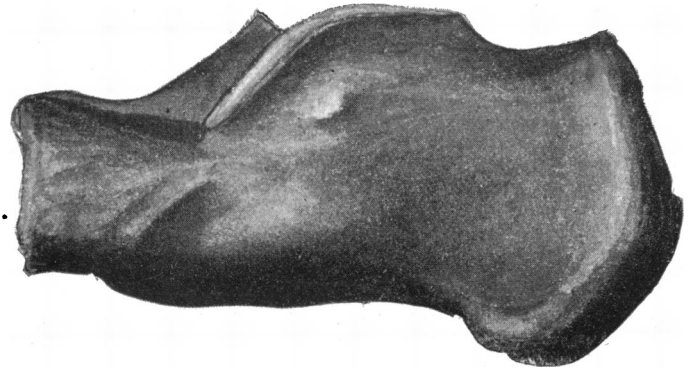

FIG. 6.—Bone 639—Showing a groove the only separation between processus trochlearis and eminentia retrotrochlearis.

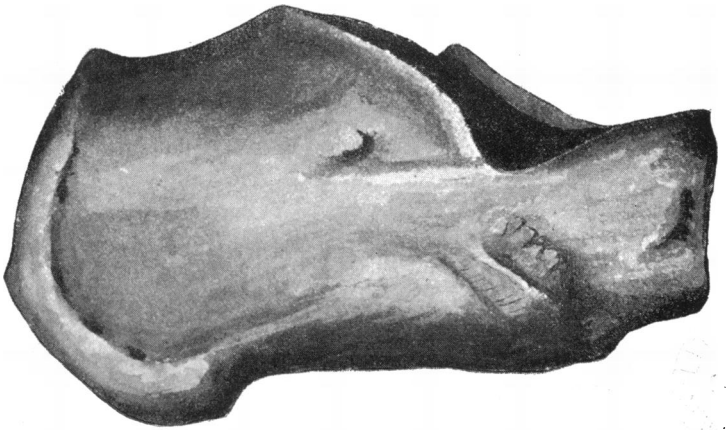

FIG. 7. – Bone W.72—Showing how ossification in the sheaths of the tendons bordering the grooves increases the eye of trochlea.

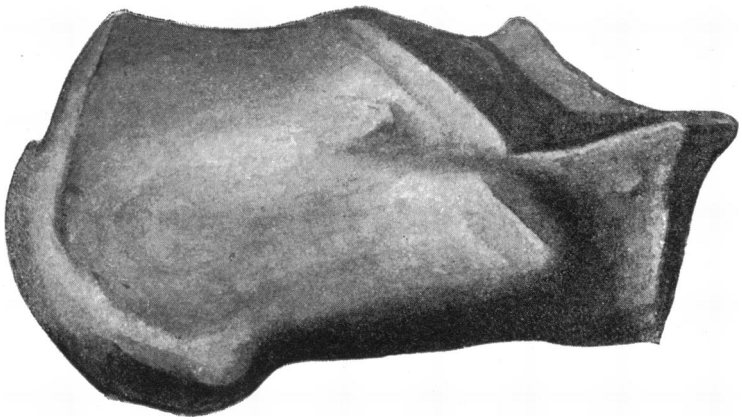

FIG. 8.—Bone 307—Glide-facets on eminentia retrotrochlearis, which extends further forward than usual (young bone).

by the anterior margins of the two processus laterales tuberis calcanei.

The chief variations in the anterior two-thirds of this area are the presence or absence of strong ridges; one especially, which starts from the lateral plantar tubercle and extends to the lateral border of the cuboid tuberosity, is occasionally a prominent ridge. In some of our specimens the part in front of the tubercle forms a bridge over a narrow cleft, probably for a vessel, but this I have not verified. The vascular holes on this surface are usually limited to the deep bay between the plantar tubercles. A large venous hole is always conspicuous here; sometimes the arterial smaller hole which lies on its medial side is small or multiple. A branch of the lateral plantar artery enters this hole. In general, there is no muscle directly attached to this trigonum, but the lateral head of the accessorius, normally attached over the calcaneo-cuboid ligament, may touch the bone.

The variations due to the extent to which the processus lateralis tuberis calcanei projects outwards and forwards will be enumerated with the varieties of the processus posterior.