Thesis

on

THE FORM OF THE PALUS

with special reference

to that of the

AUSTRALIAN ABORIGINAL

Submitted for the degree of Doctor of Medicine

by

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THE POSTERIOR ASPECT OF THE BODY AND HOCK OF THE CALF ...

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THE FORM OF THE TALUS
with special reference to that of the
AUSTRALIAN ABORIGINE.

INTRODUCTION

Owing to the courtesy of Professor Arthur Robinson I have been able to examine 174 talus taken from the Ramsay Smith Collection of Australian bones in the University of Edinburgh.

I should like to express here my sense of indebtedness to Professor Robinson for the use of these bones and suitable instruments and, also, for the other facilities which he has afforded me.

I am also indebted to Professor J.K. Jamieson for the facilities which he has provided in his department in the School of Medicine, Leeds, and for the use of material obtained from that department.

THE SKELETON OF THE AUSTRALIAN

Sir Arthur Keith (23, p713) considers the Australian native to be the "nearest approach to the common ancestor of modern mankind", though not the direct ancestor of either African or European.

Looked upon as such, the skeleton of the Australian native has a special interest for Anatomists and Anthropologists; and the primary object of this thesis is, if possible, to establish a norm for the Australian talus and, in the light of any information obtained, to examine a number of English bones. An enumeration of some of the principal points on which the Australian differs from the European skeleton may, however, not be considered out of place here.

The skull is dolichocephalic, the figures given by Turner (53a) for the cephalic index being 63-72 and, by Topinard (54), 71,4.

The vertical cephalic index is small, the figures given by Turner being 55-72, tapeinocephalic.

The milk tooth capacity of the skull is also small. Turner gives it as 993cc.-1330cc., and Topinard gives it as 1131cc. for the female and 1317cc. for the male; the skull is microcephalic.

The nasal index is platyrhine and agrees with that of Negroes, Zulus and Kaffirs in this respect, forming a *

The term Australian is, for the sake of brevity, used here and in the following pages with reference to the Australian Aborigine.
contrast with the measurements of the nasal aperture of European, Ancient Egyptian and American Indian races.

The orbital index is microsome, 72-94 according to Turner and 30,4 according to Copinari.

There is a considerable degree of prognathism and the teeth and palate are well developed. The dental index is over 11, megadont, and there is an edge to edge incisor oifice. This is well illustrated by Keith (28, p.374) and he gives the average palatal area of 10 Australian skulls as 31,3cm. compared with an average of 25cm. for the same number of British skulls.

He also gives the ratio of the palatal area to the cranial capacity as 1:40,8 for the Australian and 1:59,6 for the British skulls.

The lumbar curve, as indicated by measurements of the bodies of the vertebrae, is concave forward. Cunningham (13) gives the lumbar index as 107,8 in the Australian, koilorrhachic as in the negro (105,4), the Bushman (106,6) and in the Apes (Semnopithecus 105,1, Gibbon 107,1, Gorilla 108,1). The European index given by the same author is kyrtorrachic, 95,3.

Similarly, Man is characterised by the breadth of his sacrum and in the European its breadth is greater than its length, giving a platyhieric sacral index of 112,4 (male) and 115,8 (female). The index is, on the other hand, dolichohieric in the Australian and corresponds with that of Tasmanians, Bushmen, Hottentots, Kaffirs and Aniamanese (27, p.399). Paterson (41), however, gave the sacral index as 108 for one Australian skeleton.

When we come to consider the limb bones it is found that they tend to be long and slender. Quarry Wood (59, p235) states that the tibia is long in proportion to the body height and that its length is greater than that of any other race yet investigated, that the diaphysis is slender and the epiphyses slender and smaller than has been recorded for any other race. Also, the medial malleolus has a length almost double that of the European.

The clavicle is slender and Klaatsch (29a) describes it as "schlank und dünn".

The radio-humeral index is mesatikerkic, 76 compared with 72,4 for the European (Turner).

The head of the humerus points far back and the corpus
and metacarpus are slender (Krause, 30, p.191).

The tibio-femoral index is of the long-legged dolicho-
knemio type, Turner's figure being 82.9 as compared with the
brachyknemio type found in Europeans.

The average height of the native Australian is given
in the transactions of the Anthropometrical Committee of
the British Association as 5ft. 5ins. but there is
naturally considerable variation. W.W. Thomas (52, p.23)
states that a height of 6ft. 3ins. has been recorded in
Central Australia but that the natives are distinctly
smaller in Victoria than in Central Australia. At Lake
Tyers the average height and weight were found to be
5ft. 3\frac{1}{2} ins. and 137 lbs. for the men and 5ft. 1ins. and
114 lbs for the women.

The Talus.

The amount of literature on the bones of the foot is
large and Professor Tawcett (17, p.337) has remarked that
"the astragalus has so often been described, and so ably
too, that it is difficult to believe that anything more
can be added to the descriptions given by the various text-
books". Nevertheless, he found two previously undescribed
facets. One of those, the facies intermedia, is of the
utmost importance in the consideration of any measurements
of the trochlea.

After referring to numerous articles on the subject
one is almost compelled to agree with the statement made
by Leboucq (340, p.143) when he was discussing Prehistoric
and Australian Talii: - "Sind unsere Kenntnisse ueber dessen
Hand- und Fuss-skelet noch sehr-luckenhaft". Similarly,
Duckworth (13a, p.333) remarks "With regard to sexual
differences, information is not forthcoming, and in respect
of racial variations is but scanty". He refers to the
"exhaustive research by Volkov on the astragalus"; but in
this work, though the remark is justified, the extensive
field covered results in only a few bones from each race
or species being examined and the figures are, therefore,
not entirely reliable, in spite of all due care in carrying
out measurements.

To illustrate this, reference may be made to some of
the results of the examination of the Australian talus.
Klaatsch (29b, p.146) refers to the "Kleinheit und
Zierlichkeit" of two Australian tali which he had in his possession. The striking fact on examining a number of these bones is not the smallness and elegance, though many of them do have these qualities, but the great variety in their size and build.

To quote some actual figures: Klaatsch gave the length-breath indices of the two tali referred to as being 77 and 31, while the corresponding indices of the Australian tali to be considered here vary from 37 to 37, covering in that range Hyllobates Syndactylus and Simia Satyrus at the one end of the scale and the Krapina talus at the other. Klaatsch, from his wide experience of Australian bones, no doubt selected typical tali to illustrate the characteristics of the Australian, but Poniatowski's figures would not appear to be so reliable. He gives the relative breadth of the trochlea (150, p.3) for 5 Australian tali as varying from 53 to 63, with an average of 58. The figures for the Ramsay Smith bones are 62 to 32 with an average of 70; so that the bones examined by Poniatowski (and measured in the same way) were well below the average as shown by measurements of a larger number of bones.

Figures based on an examination of a small number of bones are, therefore, unreliable and may lead to erroneous conclusions.

It is hoped that this thesis may help to fill in one of the gaps referred to by Professor Leboucq.

General Considerations

An attempt was made to distinguish the sex of the Australian tali and group them accordingly, but this was found to be quite impossible. As the sex of only one skeleton (Cat. no. 303) was given, the question of sex will not be discussed here.

Data in regard to the age of the Australian bones are also practically nil.

It was found possible, however, to arrange many of the bones in pairs - right and left from the same individual. Figures in such cases have been taken from the average of measurements from the two corresponding bones. Figures obtained from unpaired bones, or when one bone of a pair was damaged, have necessarily been taken to represent the
measurement for the individual. Graphs and tables given are, unless otherwise stated, based on figures from individuals, since a graph compiled from separate figures for each bone will give undue prominence to any type of bone which happens to occur frequently in pairs. *

Material available was thought to be insufficient to justify statements as to differences between right and left bones.

Numbers in brackets following a quotation or the name of an author indicate the reference given in the appended list.

**Preliminary Definitions**

For purposes of measurement, photography and the taking of tracings it was found necessary to define the "normal position" of the talus, its long axis and its transverse axis.

The NORMAL POSITION has been taken as the talus lying on a horizontal plane with the under surface of the head, the processus lateralis and the tuberculum mediale of the processus posterior all touching that plane. The advantage of this position as a basis for the taking of measurements was originally pointed out by Soudier (47, p.421) and it has since been used by Volkov (57), Poniatowski (45b) and Appleton (5). It is convenient to term this plane on which the bone rests the BASAL PLANE as has already been done by the last named author.

The LONG AXIS has been taken as lying in the same vertical plane as the long axis of the trochlea and parallel to the basal plane.

The TRANSVERSE AXIS has been taken as passing through the apex of the processus lateralis and perpendicular to the vertical plane in which the long axis lies.

**Errors in Observation**

Poniatowski (45b, p.2) allows a permissible error in observation of 0,5 mm. or 1,5°. This may be a reasonable margin theoretically, or actually for some bones, but, in the case of the Australian tali, the rounding of the edges and the curvature of the lines dealt with frequently render the possible error greater than this.

Measurements given for these bones have been taken to the nearest 1 mm. or 1°. The indices and averages are

*See page 3, ER3ATA.
given correct to the nearest first decimal place.

I would protest here against the pseudo-scientific accuracy of some authors in giving their results to the second decimal place when the original measurements can only be accurate to the nearest unit. Calculation of an index or average to a smaller fraction than is justified by the accuracy of the figures upon which it is based conveys a false impression of the accuracy of the results.

To take an example from the literature on the talus, Poniatowski (110, Table 11) measured the angle between the long axes of the posterior calcaneal facet and of the trochlea in 11 bones. He gives the average angle as being 21.45° ± 0.39°, while the error in observation which he allows is 1.5°.

Calculation of Average Indices

It is to be noted that, when dealing with the ratio of one measurement to another, the ratio of the averages of two sets of measurements is not the same as the average of the ratios worked out separately for each pair of measurements, unless the ratios are all equal.

In this thesis all indices and ratios have been worked out for each bone separately and the average of these results recorded.

To work out an index by calculating the ratio of two average measurements to each other (as appears to have been done by at least one author writing on the talus) is similar to adding two fractions by simply adding the numerators and the denominators together. One example, which I have worked out to demonstrate the error possible, is that of the ratio of the direct length of the head of the talus to its surface length. The average ratio of the direct to the surface length is 53.3 : 100 for 75 of the Australian talus; the ratio of the average measurements is 33.3 : 100 for the same group of bones. The latter result would indicate that the curvature of the head of the Lewis talus is similar to that of the Australian talus, a state of affairs which inspection of the bones shows to be false.

Errata

In Figs. 3, 7, 9, 13, 17, 20, 23, 40, 41, and 12 the heading "No. of bones" should read "No. of individuals".
**Length**

The length of the talus has previously been described, broadly speaking, in two ways.

1. Measurements are made from the posterior end of the posterior process to the most prominent part of the articular surface of the head of the bone.

2. Measurements are made from the bottom of the sulcus for the flexor hallucis longus tendon to the head of the bone as in 1.

The first of these methods was adopted by Borjanović-Kramberger (80, p.244), Mollison (33, p.579) and Volkov (57, p.632). It includes in the length what is known to be a very variable factor, namely, the lateral part of the posterior process. The whole or greater part of this, as the os trigonum, may be absent from the dried specimen.

In addition to including the posterior process Volkov measures "jusqu'au point le plus saillant du bord de la surface articulaire de la tête", as shown in fig. 1.

![Fig. 1. The length of the talus as measured by Volkov.](image)

His reason for measuring the length in this way was that the majority of the bones which he used were mounted. He states at the same time that "Évidemment cette mesure doit dépasser un peu la longueur réelle". He also measures the length "dans l'axe de la poulie", but does not define that axis.

It would, therefore, seem advisable to use the second method which has already been adopted by the majority of authors including Leboucq (34c, p.144), Sewell (43a, p.334) Adachi (1, p.310), Martin (37b, p.644) and Poniatowski (45b, p.3).

Sewell defines the length as "the distance between the foremost part of the caput and the floor of the sulcus".
musculi flexoris hallucis longi`. This measurement is, presumably, along the line $CD$ in fig. 2. The line $KD$ may, however, have been used.

Poniatowski, on the other hand, measured the length with the points of a pair of straight-edged calipers touching the basal plane at $3$ and $H$. His definition is "die projectivische Entfernung des sulcus musculi flexoris hallucis longi vom entferntesten Puncte der facies articularis navicularis, und zwar bei der normalen Lage des Knochens auf eine horizontalen Ebene....."

![Fig. 2. The length of the talus.](image)

This last method enables measurements to be taken from tracings. It is easy to carry out on the actual bone, and I have adopted it in measuring the Australian tali.

The sulcus for the flexor hallucis muscle frequently slopes away below and the measurements have been taken from the most prominent part of the floor of the sulcus to the foremost part of the head in projection, that is, along the line $3H$ in fig. 2 by means of straight-edged calipers.

Volkov has used the term "en projection" to indicate the shortest distance between two points and not the distance between them projected onto a horizontal plane. Some confusion appears to have arisen in the literature as a result.

The figures obtained for the length of the Ramsay Smith Australian tali by the above method are as follows:

- **Average length** = 43.5 mm.
- **Maximum length** = 53 mm.
- **Minimum length** = 37 mm.

The total number of bones available was 151, of which 94 were in pairs, making the number of individuals 104.
The graph in fig. 3 shows the distribution of the numbers of Australian bones of different lengths. Above it are indicated the averages and extent of variation of of Sewell’s Ancient Egyptian series and of 33 Leeds tali.

![Graph showing distribution of Australian bones and comparison with Sewell's Ancient Egyptian series and 33 Leeds tali.](image)

Sewell’s figures for his 1000 Ancient Egyptian tali are as follows:

- Average length = 50mm.
- Maximum length = 55mm.
- Minimum length = 41mm.

Owing to difficulty in deciding whether certain of the Leeds tali were or were not paired only bones from one side, the right, were used. The 33 bones available gave the following results:

- Average length = 51.1mm.
- Maximum length = 53mm.
- Minimum length = 45mm.

Volkov’s figures are not comparable and Poniatoowski does not give his figures for absolute measurements.

The Australian tali are shorter than the Ancient Egyptian and these in turn are shorter than the modern type of bone as represented by the tali from the Leeds dissecting rooms.
The height of the talus has here been measured to the basal plane.

The only definitions of the height of the talus which I have been able to trace are those of Volkov (57, p.283), Jorjanović-Kramberger (80, p.244), Poniatski (45b, p.4) and Appleton (5, pp.133-134).

Jorjanović-Kramberger's definition is 'from the "trochlear höhe" to the "basis"'.

Volkov measures the height "avec le compas-glisserio a branchos inégaies en appuyant la branche longue de cet instrument contre les points les plus saluants de la face inférieure de la tête de l'astragale et la partie postérieure de cet os, vue du côté du bord interne du pied et en passant la branche courte au point le plus salissant du bord supérieur de la facette triangulaire pour la malleole interne". "La partie postérieure de cet os, vue du côté du bord interne du pied" presumably means the medial tubercle and the measurement is, in effect, the height of the medial border of the trochlea from the basal plane.

Poniatski measures from the highest point of the longitudinal groove on the trochlea, "mittlerelängskurve", to the basal plane.

Appleton used the term axial basal height to indicate the distance between the highest point of the trochlear axis and the basal plane, but gives no figures. He used the term axial height to indicate the distance between the highest point of the axis of the trochlea and the nearest point of the posterior canancan facet.

It will be seen that there is little assistance to be had from the literature as far as it could be traced, and the question arises as to which part of the trochlea is to be used as the top of the bone for purposes of measurement. There are five possibilities to be considered:-

(1) The highest point of the of the medial side of the trochlea.

(2) The highest point on its lateral side.

(3) The highest point on its medial or lateral side, whichever of the two is the higher.

(4) The highest point of the trochlea in its long axis.

(5) The highest point on the floor of the longitudinal groove on the trochlea.
The method adopted should be applicable to bones from the lower races of Man and the Apes, and, if possible, to other animals.

With regard to method 1 it has to be remembered that the medial edge of the trochlea in Apes (Gorilla and Orang) is frequently very much lower than the lateral edge, or even the longitudinal groove. A measurement made to the medial side of the trochlea will, in these cases, give a false idea of the height of the bone and is to be ruled out.

There are similar reasons, though not quite such strong ones against method 2. The lateral border of the talus is commonly stated to be the higher of the two, vide Morris (39, p.390), festut (51b, p.342), Humphrey (21a, p.535) and Lazarus (33, p.4), though many of the modern text-books are silent on the subject. In many of the Australian and Leeds talus, however, the medial border of the trochlea is higher than the lateral border. Fig. 4 shows a tracing of one of the Australian talus, no. 213/3, in which this is the case.

Fig. 4, Tracing of Australian talus in plane of transverse axis.

This may be so for other races and it would seem advisable to choose some other point from which to measure if possible.

Method 3 involves changing from one side to the other for different races (or species of animals) or, as in the case of the Australian, for different individuals of the same race, and even for right and left bones from the one individual (No. 211). Although the method is good, inasmuch as it gives the actual height of the bone at its highest part, it is preferable to have a more fixed point from which to measure.

Method 4 involves defining and finding the long axis of the trochlea and the point to be measured from will
usually fall on or close to the midpoint of a line joining the two borders. Poniatowski (152, p.3) states that the "lateral ridge" corresponds with the long axis of the trochlea, and one can infer a similar conclusion from the statement made by Norris (59, p.333) that the inferior surface of the tibia "has a broad ridge running from before backwards about midway between the lateral borders".

The groove on the trochlea of the Australian talus is, however, situated nearer the junction of the medial and middle thirds of the trochlea than the middle of that surface.

It would seem that the point from which measurements are to be made will lie at the bottom of a groove in one race and on the slope of the lateral portion of the trochlea in another.

Method 5, which is to take the height of the talus vertically from the basal plane to the highest point on the floor of the longitudinal groove on the trochlea has been adopted in measuring the Australian and Leeds tali.

It would appear to give results which are more comparable with each other when dealing with bones from different persons of the same or different races. Also, the results will be less affected by the slight damage to one or other of the edges of the under surface which is frequently present in bones which it is desirable to examine.

Poniatowski has used this method and, since Volkov is the only other author to define his method of measuring and give figures, it is not a case of adding to the existing number of methods unnecessarily.

In addition to measuring the height in this way it is desirable to measure the medial and lateral heights of the trochlea and express the results as an angle or index.

Having decided the points between which to measure the height, there are three fairly simple methods available for carrying out the measurement:

(1) the bone is placed on a glass plate (previously tested for uniformity in thickness and flatness) and the distance between the under surface of the plate and the desired point is measured by means of straight edged callipers, the lower blade being placed flat against the glass. The thickness of the plate is then deducted.
(3) Use may be made of the "coordinatenzirkel" devised by Poniatowski (150, p.3) for plotting out curves and shown diagrammatically in fig. 5. The sliding rod, 3, is graduated in millimetres so as to indicate the height of its point above a line joining the points of the blades.

Fig. 5, "Coordinatenzirkel" (Poniatowski).

(3) In practice, since tracings of the Australian tali had already been taken in the plane of the transverse axis by means of a perimeter, it was found to be simplest and most accurate to measure the height on paper along the line AB as shown in fig. 6.

Fig. 6, AB equals Height as measured for Australian Tali.

The results obtained in this way were checked by comparison with figures obtained by method 1 and were as follows for 125 Australian bones representing 33 individuals:

- Average height = 29mm.
- Maximum height = 32mm.
- Minimum height = 21mm.
The heights of 35 Leeds tali were measured for comparison with the above with the following results:

- Average height = 31.3 mm.
- Maximum height = 35 mm.
- Minimum height = 26 mm.

The graph in fig. 7 shows the numbers of Australian bones having the various measurements.

![Graph showing height measurements]

Fig. 7, Height of Australian Tali.

The Australian tali would seem to be, as in the case of the length, smaller than the modern type of bone.

**Breadth**

The breadth of the talus has been defined by several authors. The definition given by Leboucq (34c, p.144) differs from the remainder, with the exception that Martin (37b) accepts his definition. Leboucq measured from the lowest point of the fibular facet to the most prominent point on the medial tubercle. Some other authors have used the apex of the lateral process instead of the articular surface: this is preferable when dealing with the bone as a whole.

The lateral process varies in size apart from the breadth of the body of the bone but it is so much an integral part of the bone, and the difficulty of finding any other fixed point is such, that its inclusion in the breadth is necessary.

The inclusion of the medial tubercle is more open to
criticism. It varies in size as much as, or more than, the lateral process and it can be excluded by measuring to a point farther forward; that is, in the plane of the transverse axis. Its inclusion in the breadth would, therefore, seem to be an introduction of an unnecessary source of error. Leboucq (310, p.150) states that he measured the breadth as above because "iisses Tuberculum einen pragnanten Punkt des prahistorischen Talus darstellt und dieser Punkt leicht aufzufinden ist".

The definitions of Sewell (43a, p.231), Aiachi (1), Klaatsch (23c) and Poniatowski (150, p.1) are all similar. Sewell takes the "distance between the apex of the processus lateralis and the medial surface, perpendicular to the long axis of the corpus". Žorjanović-Kramberger (20, p.241) probably measured in the same way, but his description is 'from the inside to the outside'. Poniatowski measured the breadth as he did the length, taking the "projectivische Entfernung" with the points of his calipers touching the basal plane.

This last method, as in the case of the length, allows of measurements being taken, if necessary, from tracings and has been adopted in measuring the Australian and Leels tali.

The long axis of the bone has here been taken as coinciding with the long axis of the trochlea* and the breadth taken as the distance, projected onto the basal plane, between the apex of the lateral process and the farthest point of the medial surface in a vertical plane passing through the transverse axis.

The results obtained from measurements of the breadth of 100 Australian tali representing 75 individuals were as follows:–

Average breadth = 38mm.
Maximum breadth = 43mm.
Minimum breadth = 31mm.

*See pages 19 to 51.
34 right Leeds tali were measured for comparison with the above with the following results:

- Average breadth = 13.1 mm.
- Maximum breadth = 49 mm.
- Minimum breadth = 35 mm.

Thus the Australian tali are again smaller than the Leeds specimens: the Australian bones are shorter, lower and narrower.

The differences are too large to be accounted for by the fact that only right sided bones were taken from the Leeds series. This, as already indicated, was done because it was found to be impossible to arrange them in pairs with any degree of accuracy.

The absolute measurements are not of much value unless taken along with other measurements or used to obtain indices. It may safely be said, however, that the Australian tali are distinctly smaller than the modern civilised bone as exemplified by the Leeds specimens.

This is in accord with the findings of Quarry Wood (59, p.255) that the epiphyses of the Australian tibiae from the Ramsay Smith Collection are slender and smaller than has been recorded for any other race.

The Australian tali would also appear to be smaller than the Ancient Egyptian ones examined by Sewell. His figures for the breadth of 1000 bones are:

- Average breadth = 39 mm.
- Maximum breadth = 43 mm.
- Minimum breadth = 32 mm.

The average length, as already stated, is greater in the Egyptian than the Australian tali in about the same proportion as in the case of the breadth, but an element of doubt is introduced by the different method of measuring.

The breadth of 51 mm. given by Lebouq (310, p.115) for the Spy talus is not comparable to the above figures but I have measured a cast of that bone in the same manner as the Australian and Leeds tali. The breadth is 49 mm., distinctly greater than the broadest Australian bone, equal to the broadest Egyptian bone and nearly equal to the broadest Leeds bone. The length and height were 55 mm. and 31 mm. respectively.
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Poor text in the original thesis.
Some text bound close to the spine.
Some images distorted
Fig. 3 shows the numbers of Australian tali having various breadths. Figures for the Beads, Egyptian and Spy tali are placed above for comparison.

![Graph showing the numbers of Australian tali having various breadths.](image)

The factors which were found to enter mainly into the production of variations in breadth, apart from the size of the bone, were as follows:

1. The effect of variations in size of the lateral process is marked. Virchow, in the discussion following Lebouloq's paper (81c), has already stressed the part played by this process in increasing the breadth of the talus of prehistoric Man. He attributed the great breadth of the Spy talus to this, rather than to the inclusion by Lebouloq of the medial t attractiveness in the orca.

Turner (85b) and Bruck (81) both used the term *talus secundarius* to indicate the os trigonum. Pfitzner (12, p.215), however, used the term to indicate an ossicle of which he found one example at the apex of the lateral process. It was marked off 12mm. from the apex of the process by an irregular suture.

Sewell (13a, p.213) found, among his Egyptian series, one bone (No. 334) which was marked off in a manner similar to Pfitzner's specimen, and two bones (Nos. 13 & 133) with a large bony mass in front of the lateral malleolar facet. He regarded these as separate elements of the skeleton.

If this view is correct, it offers an explanation of the large amount of variation that is met with in the size of the lateral process, in the same way as the marked variations in size of the posterior process have been explained by the presence of the os trigonum.

*See, also, pages 23 to 25.
None of the Australian or Leeds tali examined showed any appearance suggesting the presence of a secondary portion of the lateral process.

Two pairs of the Ramsay Smith tali (Nos. 195/4 and 213/3), and also one pair of Australian tali which I have in my own possession, have the apex of the process placed very far forwards owing to the unossified condition of the posterior edge. These are all young bones.

(2) In the Australian tali the edge of the medial malleolar facet occasionally projects beyond the most prominent part of the medial surface and adds to the breadth if included. It has not been included in the figures given above.

(3) There is frequently a ridge present on the medial surface; this runs forwards from the rounded area for the deltoid ligament to the anterior end of the medial malleolar facet and adds to the breadth when prominent.

(4) Occasionally the medial tubercle extends far enough forwards to affect the measurement.

(5) The method used to obtain the position of the long axis of the talus may alter the position of the transverse axis and so influence the measurement of the breadth.
Length-breadth index

The length-breadth index is the one most frequently referred to by authors writing on the talus. Only one method of calculating it is used but, unfortunately, the results obtained must vary with the methods used when measuring the length and breadth of the bone, so that some of the figures given are scarcely comparable with others.

The index is the breadth of the bone expressed as a percentage of its length and was worked out for 89 of the Australian tali representing 63 individuals:—

Average length-breadth index = 79  
Maximum length-breadth index = 87.5  
Minimum length-breadth index = 71.5.

Similar results were obtained on adding the figures for some bones where it was found necessary to estimate the position of the transverse axis by eye when measuring the breadth. The addition of the figures so obtained would bring the number of bones up to 111 and the number of individuals up to 83, while the average index becomes 73.5.

Fig. 9 shows the frequency of the different sizes of index.

![Graph showing frequency of length-breadth index](image)

Fig. 9, Length-breadth Index of Australian Tali.

The Leeds tali are either longer or narrower than the above. Calculations of the length-breadth index from measurements of 33 right bones gave the results indicated below:—

Average length-breadth index = 74  
Maximum length-breadth index = 37  
Minimum length-breadth index = 37

I have also measured four full-time foetal tali taken from still-born children without any gross deformity.
The length-breadth indices of these were:

No. 1 .... 75.7
No. 2 .... 71.5
No. 3 .... 76.5
No. 4 .... 75.3

No. 2 was taken from an exceptionally large and well developed child. The remaining three were all of practically the same size, the measurements being within 0.2 mm. of each other.

The figures given by Sewell (43a, p. 231) for 1000 Ancient Egyptian tali are:

Average length-breadth index = 78
Maximum length-breadth index = 91.7
Minimum length-breadth index = 68.7

He notes the variability of the index in bones of the same length. This is easily accounted for by the causes of variation in the breadth already mentioned. Sewell attributed it to variations in the size of the lateral process.

Neanderthal Man apparently possessed a broad talus. Fraipont (19, p. 19) has stated that the talus of the Spy skeleton is "broader in proportion than any other race" and Lebouoq (340, p. 145) gives its length-breadth index as 91.

Owing to the inclusion of the medial tubercle in the breadth this figure is too large in comparison with those of other authors. Measurement of a cast of this bone by the same methods as have been used for the Australian tali reduces the index to 37.

Sorjanović-Kramberger (20, p. 214) gives the index as 85 for the Krapina skeleton. He, however, includes the posterior process in the length, thereby rendering the index too small when compared with the figures given by other authors. In addition, his method of measuring the breadth is doubtful.

Lebouoq (340, p. 115) gives the average length-breadth index of all Neolithic tali measured up to 1902 as 80, but does not state how many bones were used in obtaining that figure.

He also gives (ibid.) the average of 40 modern tali as
being 77,33. Klaatsch (ibid.) gives the European average as 73–75, when the breadth is measured in the plane of the transverse axis. He also gives the indices of two Australian tali as 77 and 31.

Poniatowski (150, p.5), using the same methods as I have employed here for the Australian and Leads bones, gives the figures shown in the table below.

<table>
<thead>
<tr>
<th>Race or Species</th>
<th>Number of bones measured</th>
<th>Length-breath index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hylobates siamensis</td>
<td>11</td>
<td>74,3</td>
</tr>
<tr>
<td>Simia satyrus</td>
<td>5</td>
<td>73,8</td>
</tr>
<tr>
<td>Gorilla gorilla</td>
<td>7</td>
<td>32,3</td>
</tr>
<tr>
<td>Burmese</td>
<td>3</td>
<td>77,3</td>
</tr>
<tr>
<td>Tibetan</td>
<td>7</td>
<td>73,3</td>
</tr>
<tr>
<td>Australian</td>
<td>6</td>
<td>73,2</td>
</tr>
<tr>
<td>Tyrolean</td>
<td>21</td>
<td>32,3</td>
</tr>
<tr>
<td>Alsatian</td>
<td>20</td>
<td>31,00</td>
</tr>
<tr>
<td>Patagonian</td>
<td>5</td>
<td>31,4</td>
</tr>
<tr>
<td>Maori</td>
<td>6</td>
<td>32,7</td>
</tr>
</tbody>
</table>

He divides the Anthropoids into two groups, the Zibon and Orang with a narrow talus and the Gorilla and Chimpanzee with a broad talus.

He also notes the marked variability in the size of the index in the case of the Gorilla. It ranges from 31 and 31, on the one hand, to 33 and 132 on the other, even with the small number of bones which he examined. He remarks that the figures give little information and points out, in connection with that remark, that the Australian Aborigines is placed next to a European race.

A survey of the above figures given by various authors indicates the necessity for working from averages based on measurements of a large number of bones in each series.

An attempt has been made to represent the state of affairs graphically in fig. 10 (overleaf).

Léoncourt's figures are too large and allowance for the different method of measurement would probably reduce them to below 73, so that they would agree with Klaatsch's figures for the usual modern European index, i.e., 73–75.

The average for the 33 Leads tali examined is 74, but the majority of the indices lie between 71 and 73 and the numerical average is raised by five exceptions above these.
The exceptions above 75 are 77, 79, 31, 34 and 97, while bones from two individuals only had indices below 71; 87 and 89 being their value.

The average length-breadth index for modern civilised races can, therefore, fairly safely be taken as lying between 70 and 75 as stated by Klaatsch.

The average length-breadth index for modern civilised races can, therefore, fairly safely be taken as lying between 70 and 75 as stated by Klaatsch.


Poniatowski's figures, though based on numbers of bones that are too small to be reliable, indicate that the Orang and Gibbon may have very similar indices to modern civilised races.

His figures for the Tyrolean, 80, and for the Alsatian, 81, would place these races alongside Neolithic races.

The Australian and Ancient Egyptian tali have similar indices, 73 and 79, and Neolithic tali have an average index, 80, only slightly larger than these.

The comparatively small range of variation of the Australian indices compared with that of a smaller number of British indices is worthy of note. The index for the Australian is more constant than that of the Leeds specimens in spite of the fact that all ages are included in the Australian series, while the Leeds bones are, with one exception, taken from bodies over middle age. The stocks from which the latter are derived may be more mixed.

The Patagonians would appear to have a high index also, 81, if any reliance can be placed on an examination of five bones.

The Gorilla has a large index and the indices of the two Neanderthal tali are also large, approaching the average.
given by Poniatowski for the Gorilla.

Although the last statement is suggestive, it is well to remember that the number of Neanderthal bones available is exceedingly small and that many of the Australian, Ancient Egyptian, and even three of the bones from the Leeds dissecting rooms, have indices within the range of variation of the index for the Gorilla.

These bones, though having large indices, have by no means a gorilline appearance.

The mental impression I have received of the talus of the Gorilla is that it consists of a broad mass of bone with rough tuberosities: over this mass the articular surfaces are splayed out in an attempt to cover it. In other words, I am of opinion that the great breadth of the talus of the Gorilla in proportion to its length is largely due to the presence of rough prominences for the attachment of ligaments.

Variations in the size of these prominences would account for the great variability found in the length-breadth index by Poniatowski.

Leboucq was of opinion that a large medial tubercle is characteristic of the prehistoric talus. Size of this tubercle is largely a manifestation of large prominences for the attachment of ligament.

Virchow, on the contrary, was of opinion that the breadth of the Spy talus was due to the prominence of the lateral process, rather than to the medial tubercle.

Examination of a cast of the Spy talus shows that, when the breadth is measured in the same way as has been used here for the Australian and Leeds talus, it is reduced to 48 mm. This is still large in proportion to the length, the length-breadth index being 37.

The lateral process of the Spy cast projects 9.5 mm. beyond the lateral edge of the trochlea in the transverse plane, and comprises 30% of the total breadth projected onto that plane.

For comparison the amount of projection of the lateral processes of 33 Leeds talus was worked out in the same way. The average projection proved to be equal to 15.3% of the breadth, the maximum projection was 20.0% and the minimum projection was 9.2%. Three out of the 33 Leeds bones had a projection of the lateral process equivalent to 20% of

*See page 23, J 3.
the breadth of the bone concerned.

The Spy talus has therefore a large lateral process, but no larger than some of the Leeds bones.

The table in fig. 11 shows, further, that the index, in the case of the Leeds specimens, varies to a large extent apart from the size of the lateral process.

<table>
<thead>
<tr>
<th>No.</th>
<th>Index Averages</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>97</td>
</tr>
<tr>
<td>3</td>
<td>74</td>
</tr>
<tr>
<td>13</td>
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</tr>
<tr>
<td>17</td>
<td>73</td>
</tr>
<tr>
<td>3</td>
<td>73</td>
</tr>
<tr>
<td>5</td>
<td>73</td>
</tr>
<tr>
<td>12</td>
<td>74</td>
</tr>
<tr>
<td>11</td>
<td>75</td>
</tr>
<tr>
<td>21</td>
<td>75</td>
</tr>
<tr>
<td>22</td>
<td>73</td>
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<tr>
<td>30</td>
<td>77</td>
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<td>23</td>
<td>73</td>
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<td>13</td>
<td>73</td>
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<td>17</td>
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<tr>
<td>13</td>
<td>73</td>
</tr>
<tr>
<td>3</td>
<td>71</td>
</tr>
<tr>
<td>7</td>
<td>72</td>
</tr>
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<td>11</td>
<td>73</td>
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<td>14</td>
<td>73</td>
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<td>13</td>
<td>73</td>
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<td>23</td>
<td>75</td>
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<tr>
<td>33</td>
<td>71</td>
</tr>
<tr>
<td>728 - 3 = 71, 5</td>
<td></td>
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<tr>
<td>14</td>
<td>73</td>
</tr>
<tr>
<td>31</td>
<td>73</td>
</tr>
<tr>
<td>115 + 3 = 72, 5</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>75</td>
</tr>
<tr>
<td>23</td>
<td>73</td>
</tr>
<tr>
<td>22</td>
<td>73</td>
</tr>
<tr>
<td>33</td>
<td>73</td>
</tr>
<tr>
<td>113 + 3 = 71, 5</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>72</td>
</tr>
<tr>
<td>13</td>
<td>73</td>
</tr>
<tr>
<td>143 + 3 = 74</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>73</td>
</tr>
<tr>
<td>23</td>
<td>73</td>
</tr>
<tr>
<td>73</td>
<td>73</td>
</tr>
</tbody>
</table>

Percentage projection of lateral process in Leeds specimens.

Fig. 11.

The length-breath index of the Spy talus then becomes 77,2 as compared with 73 for the Leeds bone.

If the projection of the lateral process of the Spy talus is now assumed to be 7,2mm., then the breadth becomes 45,7mm. and the projection becomes 15,75% of the breadth. This is approximately the average projection (15,3%) of the Leeds bones and the length-breath index of the Spy cast becomes 33 as compared with 74 for the average Leeds bone.
Finally, Leeds tali having a projection of the lateral process equivalent to 20% of the breadth (Nos. 1, 3, 13) have an average length-breadth index of 79.3 as compared with 87 for the Spy cast which also has a projection of 20%.

In each case the index for the Spy talus is larger than that for the corresponding Leeds bones.

The principal factors, other than the size of the lateral process, concerned in the production of a large length-breadth index for the Spy talus are the length and angle of the neck* and the presence of a pronounced ridge on the medial surface. These will be mentioned later under the headings "Angle of the Neck" and "Medial Surface."

I have worked out the amount of the projection of the lateral process for the Australian tali in the same way as for the above.

The method of carrying out the measurement was to place the bone on a flat surface with the apex of the lateral process touching the upright limb of a metal L clamped to the surface. The lateral border of the trochlea was marked out with white chalk and the distance between it and the upright was measured by means of a pair of internal calipers. The bone was placed with the long axis of the trochlea parallel to the surface of the upright and the measurement taken in the plane of the transverse axis, i.e., perpendicular to the surface of the upright and at the level of the apex of the lateral process.

![Diagram of measuring the projection of the lateral process](image)

The results of these measurements of the lateral process, expressed as a percentage of the total breadth, are shown over-leaf.

*See foot-note to page 27.
For the Australian they proved to be as follows for 38 bones from 63 individuals:

- Average projection = 21.5%
- Maximum projection = 23.3%
- Minimum projection = 12.7%

The numbers of Australian bones with the various percentages are shown in fig. 13 along with the figure for the Spy cast and the average and range of the Leeds tali.

![Graphs showing projection of lateral process and relation of length-breadth index to projection of lateral process](image)

Fig. 13.  

It will be seen that the relative size of the lateral process of the Australian talus is well above that of the 33 Leeds specimens, and that the Spy talus occupies a position close to the Australian average.

The length-breadth index in the case of the Australian shows, as might be expected, a definite relationship to the amount of projection of the lateral process. Fig. 14 is a graph to demonstrate the tendency for a large length-breadth index to be the natural accompaniment to a large lateral process. The irregularity of the curve, however, shows that, as in the case of the Spy and Leeds talus, there are other factors at work as well as the size of the lateral process. To take an example, the Australian tali having a projection of 20%, a figure fairly near the average, have length-breadth indices varying from 73 to 30.

Grouping of the Australian tali according to the size of their length-breadth indices did not reveal to the eye any difference in the types of bone with large or small indices.
In conclusion, it may be said that the Australian talus is broader in relation to its length than bones from modern civilised races; the same is true of prehistoric tali and, probably of primitive races such as the Patagonians. The tali from the Tyrol and Alsace which were measured by Poniatowski have indices as large as the average of Neolithic tali out, as he does not state which parts of these bones were mainly responsible for the increased index, and in view of the accepted smaller index for European tali, it is impossible to draw any conclusions. Possibly the hilly nature of the country may be a factor.*

The causes of variation in the size of the length-breath index of the talus are too many to allow of definite conclusions being formed unless from average figures based on a close examination of large numbers of bones from different races.

The principal causes of variation observed during the examination of the Australian and Leeds tali were the size of the lateral process, the strength of the ligaments as determined by the prominence of the sites of their attachments and the angle of the neck.

The lateral process is relatively prominent in the Spy and Australian tali. Its prominence may be influenced by the position or angle of the posterior facet for articulation with the calcaneus, since this facet passes as far laterally as the edge of the under surface of the process. The degree of prominence may depend on the size and development of the fibula and the mode of transmission of the body weight to the foot. Or, there may be developmental tendencies in the talus itself. This is suggested by the possibility of a talus secundarius as defined by Pfitzner and Sewell.

Volkov (57), in his summary, has already remarked of the lateral malleolar facet that "elle est la plus large dans les races inférieures et la plus étroite chez les Européens".

Fig. 15 (over-leaf) illustrates an Australian talus (No. 201/3 L.) which owes its large length-breath index, 80, to the prominence of its lateral process. The projection of the process is equivalent to 30% of the total breadth.

*Races inhabiting hilly regions usually have high arches, and races dwelling on flat plains tend to be flat footed. A high arch probably means a large vertical angle of the neck, i.e., bending of the talus upon itself, with slight consequent shortening of the length of the talus.

See, also, the relation of the vertical angle of the neck to the length-height index, page 37.
The size of prominences for the attachment of ligament will not affect the measurement on the lateral side, since the anterior and posterior talo-fibular ligaments are attached medial to the prominent part of the lateral process.

The prominences on the medial surface are the medial tubercle and the ridge which runs forwards from it to the anterior end of the malleolar facet.

The medial tubercle is specially prominent in most prehistoric talus and both it and the ridge running forwards are marked in the Australian bones. Fig. 15 shows a tracing of a Gorilla talus and the part played by the medial tubercle in increasing the breadth.

The size of the medial tubercle would seem to be responsible for the irregularity in the size of the length-breadth index in the case of the Gorilla, and would depend largely on the weight of the body and, also, on the environment and use of the foot, e.g., on rough ground. An endocrine factor may also have to be considered here.

A large angle of the neck, in a horizontal or vertical plane, tends to reduce the length of the bone as measured. The former angle depends largely on habits, while the latter is associated with the degree of development of the arch of the foot.

In other cases the factor which is mainly responsible for changes in the index is the length of the neck as, for example, in the case of No. 212/3 shown in Fig. 16. This bone has a comparatively small index in spite of the absence of any projection posteriorly or medially.
**Length-Height Index**

The length-height index of the talus is the height of the talus expressed as a percentage of its length. The index will naturally vary with the methods of measuring the length and height which have already been discussed.

The only figures available for comparison with the results obtained here are those of Volkov (§7, p.332) and Poniatowski (15b, p.8). The figures given by Volkov will probably be too small as, though his height will in most cases be slightly large owing to the method of measurement to the highest point on the medial margin of the trochlea, this is counterbalanced by his inclusion of the posterior process in the length. Poniatowski's figures should correspond with those obtained here as he used the same methods of measuring the breadth and length as have been applied to the Australian and Leeds tali.

The figures obtained for the Australian talus from measurements of 120 bones representing 32 individuals were:

- Average Length-height Index = 53.9
- Maximum Length-height Index = 63
- Minimum Length-height Index = 51.5

The majority of the indices lie between 54 and 59 as will be seen from fig. 17 which indicates the numbers of bones with the various sizes of index.

![Graph showing Length-height Index](image)

**Fig. 17, The Length-height Index of the Australian talus.**

Volkov's figures are scarcely comparable with the above but he places the Apes in the following order of height:

- Orang - Gibbon - Chimpanzee - 3orilla

The Orang has the lowest and the 3orilla the highest talus. He also states that the female Orang, Gibbon and Chimpanzee have higher tali than the males of these species,
especially in youth, and that the talus is higher in the walking than in the climbing animals.

Poniatowski gives the figures shown below and also makes the statement that the length-height index is 54 in the case of the Chimpanzee.

<table>
<thead>
<tr>
<th>Race or Species</th>
<th>Number of bones measured</th>
<th>Length-height Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simia Satyrus</td>
<td>5</td>
<td>44,8</td>
</tr>
<tr>
<td>Hylocoetes Syndactylus</td>
<td>11</td>
<td>49,32</td>
</tr>
<tr>
<td>Gorilla Gorilla</td>
<td>7</td>
<td>56,4</td>
</tr>
<tr>
<td>Tibetan</td>
<td>8</td>
<td>53,3</td>
</tr>
<tr>
<td>Burmese</td>
<td>8</td>
<td>57,3</td>
</tr>
<tr>
<td>Patagonian</td>
<td>5</td>
<td>57,3</td>
</tr>
<tr>
<td>Australian</td>
<td>8</td>
<td>53,3</td>
</tr>
<tr>
<td>Alsatian</td>
<td>22</td>
<td>53,32</td>
</tr>
<tr>
<td>Pyrolean</td>
<td>24</td>
<td>59,25</td>
</tr>
<tr>
<td>Maori</td>
<td>8</td>
<td>60,3</td>
</tr>
</tbody>
</table>

He again divides the Apes into two groups, the Chimpanzee and Gorilla with a high talus - and the Gibbon and Orang with a low talus. This agrees with the findings of Volkov.

Measurements from the 33 right Leeds tali previously mentioned gave the following results:

Average Length-height Index = 53
Maximum Length-height Index = 63
Minimum Length-height Index = 52

These indices were arranged as in fig. 13.

![Graph showing the length-height index of Leeds Tali.](image)

Fig. 13, Length-height Index of Leeds Tali.

A comparison between figs. 17 and 13, and between the average figures available, indicates that the Australian talus is slightly flatter than the modern type of bone.

The differences are too slight to carry much weight
when taken alone, but it will be seen later that, when taken along with the angle of the neck in a vertical plane, the results obtained for the length-height index are supported. Also, the length-height index is more constant than, for example, the length-breadth index and any differences between the averages for different races gains an added significance.

The factors which influence the value of the length-height index are those which affect the measurements of the length and height. Of these, the angle of the neck in a vertical plane will affect both the length and the height and must play an important part in determining the size of the index. This angle would appear to vary with the degree of development of the arch of the foot, and so there is a probability that the length-height index is to be linked up with the development of the arch.

The Angle of the Neck in a Vertical Plane

Virchow (582, p.235) and Sewell (13a, p.235) have each devised methods of measuring the angle formed between the neck of the talus and its body in a vertical plane.

Virchow measured the angle between a line drawn perpendicular to the 'middle point' of the trochlear surface (midway between its anterior and posterior borders) and a line perpendicular to the facies articularis navicularis at a point equidistant from its upper and lower borders.

Sewell used, as his vertical, a line drawn through the middle of the upper curved border and the middle of the apex of the lateral malleolar facet.

Virchow's method is manifestly inapplicable to the Australian tali owing to the irregular curvature of the anterior border of the trochlea and the frequent prolongations of it forwards. Sewell discarded the vertical line used by Virchow for this reason. The posterior border of the trochlea is also variable and, in addition, the variable curvature of the trochlea from side to side increases the difficulties.

Sewell's method is easier to carry out, but the procedure of taking a line perpendicular to the surface of the heel (which part of Virchow's method he retains) cannot give any degree of accuracy.
The angle of the neck in a vertical plane is intended to show the amount of inclination of the neck downwards and forwards. Why not express it as such, and measure the angle which the axis of the neck makes with the horizontal when the bone is in the normal position?

With this end in view a thread was stretched, as in fig. 19, from a fixed point, A, to an upright rod and tied round it at B. A piece of elastic was interposed at C in order to keep the thread taut and the thread was tied so that it could slide up and down the rod. The angle between the thread and the horizontal could thus be adjusted.

![Fig. 19.](image)

The talus was then placed on the plane AD with its medial surface close to the thread. Its position and the inclination of the thread were then adjusted till the thread lay, as nearly as could be judged by eye, parallel to the axis of the neck. The angle DAB was then measured with a protractor to the nearest 1°. The axis of the neck was taken as lying midway between the upper and lower borders seen in silhouette.

This method of adjusting the position of the thread is, I am aware, open to criticism owing to the errors possible as a result of the personal factor being large. It is, however, in my opinion, as accurate as the two previously described methods, if not more so. The adjustment of needles perpendicular to curved surfaces has presumably to be done by eye, and the result of the measurement depends too much on the position of the borders of the surfaces concerned: they may be either sinuous or indefinite.

Virchow's method, were it feasible, is the rational one as regards function, since it indicates the mean positions of the bones articulating with the surfaces in question.
The inclination of the necks of the Australian tali which were sufficiently intact were measured in the way described. Only right bones, 66 in all, were used in obtaining the results which are shown below:

Average Angle of the Neck in a Vertical Plane = 15.7°
Maximum Angle of the Neck in a Vertical Plane = 23°
Minimum Angle of the Neck in a Vertical Plane = 3°

The distribution of the bones having the various angles is shown in Fig. 20.

![Graphs showing distribution of neck angles](image)

These figures can be converted into the angle made between the axis of the neck and a vertical line by the addition of 90°, and would then become 105.7°, 113° and 93° respectively for the average, maximum and minimum. This method of indicating the amount of the inclination of the neck is, however, to be avoided, since it suggests the possibility of the figures being comparable to those given by Virchow and Sewell.

The angle made between the neck of the talus and the horizontal was also measured for 32 right Leeds tali and the figures obtained were:

Average Angle of the Neck in a Vertical Plane = 16.1°
Maximum Angle of the Neck in a Vertical Plane = 19°
Minimum Angle of the Neck in a Vertical Plane = 13°

The numbers of bones with the different sizes of angles are shown in Fig. 31.

Sewell (13a, p.193) concluded that "from the measurements of these two angles, horizontal and vertical, it is obvious that the foot of the Egyptian possessed a less strongly marked arch than the European of the present day and was altogether flatter, and thereby more closely
resembled the foot of the Negro races". The only figures he gives for the vertical angle are his own for the Ancient Egyptian, 112°, and Virchow's for the deformed Chinese foot 117°, and the modern European, 121°. His conclusion appears to me to be too sweeping unless there is other work to support it. Virchow used a different method of measuring the vertical angle; and the angle in a horizontal plane has not, so far as I am aware, been shown to vary with the degree of arching of the foot.

Bryce (7, p.133) says of the angle of the navicular in the vertical plane as measured by Virchow: "...in lower races it is greater, the foot being flatter or less arched". This is a contradiction of Sewell's conclusion which suggests that a highly developed arch is the accompaniment of a large angle of the navicular in the vertical plane.

I have been unable to trace the source of Bryce's statement, and would agree with Sewell, as far as the vertical angle is concerned, for the following reasons.

If the calcaneus is tilted up at its anterior end and the arch of the foot is thereby increased, it follows that the anterior pillar of the arch must slope downwards and forwards at an increased angle. To articulate with the proximal end of this pillar the surface of the head of the talus will be directed downwards at a greater angle than would otherwise be the case. The works of Virchow and Volkov support this view.

Volkov found that the calcaneus was inclined at a considerable angle to the horizontal plane in races where the arch of the foot is well developed, less so in the lower races where the arch of the foot is poorly developed and least so in the Apes where the calcaneus is practically horizontal and the arch of the foot is usually said to be absent. The figures relating to the inclination of the calcaneus, quoted by Anthony (4) from Volkov, are:

<table>
<thead>
<tr>
<th>Race</th>
<th>Angle</th>
</tr>
</thead>
<tbody>
<tr>
<td>European Adult</td>
<td>14° (Male) &amp; 16° (Female)</td>
</tr>
<tr>
<td>European New-born</td>
<td>5° or less</td>
</tr>
<tr>
<td>Weddas</td>
<td>3° (Male) &amp; 10° (Female)</td>
</tr>
<tr>
<td>Negroes</td>
<td>6° (Male) &amp; 4° (Female)</td>
</tr>
<tr>
<td>Lower Apes and Anthropoids</td>
<td>Nil.</td>
</tr>
</tbody>
</table>
Fig. 22 is a tracing from an X-ray photograph of the deformed foot of a living Chinese woman (Virchow). It illustrates the tilting up of the calcaneus, accompanied by an immense exaggeration of the long arch of the foot, which is present in cases of this deformity.

The conditions shown in the sketch are, in an extreme form, those suggested as likely to produce a large angle of the neck in a vertical plane, and they are accompanied, as expected, by a large angle, 23° more than in the case of the European bones measured by Virchow.

The above cannot be said to prove that a large vertical angle of the neck of the talus is a necessary corollary to the presence of a well developed arch of the foot, and I regret that I have been unable to procure any specimens showing the conditions present in cases of pes planus and pes cavus.

I am, however, indebted to Professor M.J. Stewart for permission to examine two specimens (Nos. A/655 and A/361) from the Pathological Museum in the Leeds School of Medicine.
No. A/305 is the skeleton of a foot showing a considerable degree of talipes equinus which has been accompanied by shortening of the calf muscles.

No. A/381 is a similar specimen, but there has been little or no shortening of the calf muscles.

Photographs of the two specimens are shown in fig. 23. The difference in the positions of the calcaneus in the two specimens has produced what amounts to a pes planus plus extreme extension of the ankle joint in the first case, and a mild degree of pes cavus, plus the same extension, in the second case.

No. A/381

No. A/305

Fig. 23.

The striking changes in the talus, apart from the apparent lengthening of the neck as a result of the extreme extension and consequent displacement of the trochlea, are the long, low, flat appearance in A/305 and the high, arched appearance in A/381.

The bones were, unfortunately, articulated and varnished, so that accurate measurements could not be made. The approximate results obtained are shown (over-leaf) with the average figures obtained for the Australian and Leels
tali:-

<table>
<thead>
<tr>
<th>Length-height Index</th>
<th>Vertical Angle of Neck</th>
</tr>
</thead>
<tbody>
<tr>
<td>A/361 (high arch)</td>
<td>81</td>
</tr>
<tr>
<td>Leeds average</td>
<td>58</td>
</tr>
<tr>
<td>Australian average</td>
<td>53,9</td>
</tr>
<tr>
<td>A/905 (low arch)</td>
<td>50</td>
</tr>
</tbody>
</table>

These figures are in agreement with the suggestion that the vertical angle of the neck and the length-height index vary together and with the degree of development of the arch of the foot.

It should perhaps be noted that, although Virchow's method of measuring the vertical angle of the neck gives results fairly comparable to those obtained by the method used here when the trochlea is not much displaced, it will not do so if applied to bones such as the above pathological specimens. It indicates the angle between the normal position of the leg and the anterior pillar of the arch of the foot. In the case of the deformed Chinese foot the posterior pillar of the arch is displaced to about the same degree as the anterior one so as to keep the position of the trochlea approximately normal.

Relation of Length-height Index to Vertical Angle of Neck

It has already been pointed out in the section on the length-height index that the vertical angle of the neck must influence that index considerably. It seems reasonable also to suppose that the angle and index might run parallel and have a similar significance.

The vertical angle of the neck of each of the 36 Australian tali was, therefore, compared with the length-height index, and the results show that the two criteria vary together.

Thus, for 36 Australian tali:-

Average L-H.Index = 56,7 : Av. Angle = 15,7°
For bones with L-H.Index over 56,7 : Av. Angle = 18,5°
For bones with L-H.Index under 56,7 : Av. Angle = 14,7°
For bones with Angle over 15,7°: Av. L-H.Index = 57,4
For bones with Angle under 15,7°: Av. L-H.Index = 53,3

Bones having a length-height index below the average have a vertical angle of the neck which is below the
average. Bones with a length-height index above the average have an angle which is above the average. The converse is also true.

Similarly, for 32 Leeds tali:

<table>
<thead>
<tr>
<th>Condition</th>
<th>Average L-H. Index</th>
<th>Average Angle</th>
</tr>
</thead>
<tbody>
<tr>
<td>For bones with L-H. Index = 53.0</td>
<td>Av. Angle = 16.1°</td>
<td></td>
</tr>
<tr>
<td>For bones with L-H. Index over 53.0</td>
<td>Av. Angle = 16.6°</td>
<td></td>
</tr>
<tr>
<td>For bones with L-H. Index under 53.0</td>
<td>Av. Angle = 15.7°</td>
<td></td>
</tr>
<tr>
<td>For bones with Angle over 15.1°</td>
<td>Av. L-H. Index = 53.5</td>
<td></td>
</tr>
<tr>
<td>For bones with Angle under 15.1°</td>
<td>Av. L-H. Index = 57.8</td>
<td></td>
</tr>
</tbody>
</table>

The differences in the figures are slight, but are constant in spite of the small numbers of bones used; and indicate that the length-height index varies with the angle of the neck measured in the vertical plane, and, therefore, probably with the degree of development of the arch of the foot.

Also, the method adopted for measuring the angle of the neck is sufficiently accurate for practical purposes, and slight differences between the average figures for different groups of bones are significant.
The Angle of the Neck in a Horizontal Plane

The size of the angle made between the neck of the talus and its body and measured in a horizontal plane has been described by many authors for different races of Man and species of animals and for the foetus.

In 1881 Parker and Shattock (10) measured it by means of a thread placed "along the mid-line of the trochlear surface parallel to the inner border" and another thread "along the outer margin of the neck" as is shown in fig. 24 which is a tracing taken from one of their illustrations. A third thread, at right angles to the one along the trochlea, was used to assist in obtaining the position of the latter.

Fig. 24, from Parker and Shattock (40, fig. 1)

Scudder (47, p. 184) used the same method as Parker and Shattock, and pointed out that the slightest variation in position of the threads or bone alters the angle distinctly. He used the normal position of the talus as it has been defined for measurements of the Australian and Lee's tali here.

Sewell (48a, p. 235) used a similar method.

Volkov (57, p. 684) measured the angle between "l'axe de la tête de l'astragale indiquée par l'intersection des deux diamètres (transversal et longitudinal) de sa surface articulaire" and the axis of the trochlea.

Adachi (1, p. 317) adopted a similar method to that used by Volkov.

Aitken (3, p. 489) measured the angle "between the axes of the neck and of the body".
Poniatowski (45b, p.17) measured the angle between the long axis of the neck and the sagittal plane. He does not state how he determined the position of the axis of the neck, but defines the sagittal plane as passing through the midpoints of two lines drawn between the lateral and medial borders of the trochlea anteriorly and posteriorly. The exact position of these two lines is not stated and the shape of the trochlear borders in the bones I have examined (Australian and other) renders this necessary if any degree of accuracy is desired.

In carrying out his measurements Poniatowski employed needles to fix the position of the lines used. He allowed a possible error of 1½° because the axis of the neck could only be determined approximately.

The angle of the neck measured in this way is slightly greater than the angle between the borders of the neck and trochlea.

With regard to the method used by Volkov and Adachi, "l'axe de la tete" is difficult to estimate accurately, and the axis of the trochlea is not defined by these authors.

Why Parker & Shattock and Scudder should have used lines "along the middle of the trochlear surface" and " midway between the lateral borders of the trochlear surface", in each case parallel to the inner border of the trochlea, is difficult to understand.

A line along the middle of the trochlea cannot be parallel to the medial border of the trochlea, since that surface narrows distinctly as its posterior end is approached. To stretch a thread immediately over the medial border must necessarily be more accurate than to draw a line parallel to the border at some distance. Also, though it should not be necessary to mention it, any line must make equal angles with any parallel lines in the same, i.e., the horizontal, plane.

The reasons put forward to support the use of the lateral border of the neck and the medial border of the trochlea are that the medial border of the neck is, in many cases, practically non-existent and the axis of the neck is difficult to define; the lateral border of the trochlea is said to be curved and the medial border is said to be straight. Sewell (13a, p.337), for example, says that the medial border of the trochlea of the Ancient Egyptian talus
is very nearly straight, while the lateral border is longer and curved.

My own experience with the Australian tali is that the lateral border as seen from above is frequently straight, while the medial border curves away at its anterior end.

The lateral border of the neck is seldom straight, and is frequently very much curved. It may, in addition, be distorted by the presence of a tubercle at the lateral end of the ridge present in most bones on the upper surface of the neck. Fig. 25 shows tracings of the lateral borders of some of the Australian tali (in projection). The difficulty to be experienced in drawing straight lines parallel to these borders is obvious. No. 244 illustrates one of the easiest types to deal with.

To summarise the position, practically all the lines available for the measurement of the angle of the neck of the talus are curved, so that any angle measured must vary in size according to which point of the curved line the measuring line touches as a tangent. This becomes very evident on attempting to measure a series of bones such as the Ramsay Smith Australian tali.

The axis of the neck may be estimated approximately by placing a thread over the neck and judging the correct position - as nearly as possible midway between the borders by eye.
To obtain figures for the angle of the neck of the Australian bones I have used two methods. In the first, I have followed the procedure adopted by Sarrell, and have measured the angle between two threads stretched directly above the lateral border of the neck and the medial border of the trochlea respectively, and in a horizontal plane.

In the second, I have measured the angle between two threads stretched above the long axes of the neck and the trochlea. The threads were placed, as nearly as could be judged by eye, midway between the medial and lateral borders of the parts concerned, and the average of three measurements taken.

The average angle of the neck estimated by the first method (fig. 26, B.) worked out at 23° for bones from 107 individuals, the maximum being 43°, and the minimum 3°.

The average by the second method (fig. 26, A.) was 25.1°, the maximum 37° and the minimum 11°.

The numbers of bones having the different angles are shown in fig. 26. The graph A shows the figures for the angle between the axes of the neck and trochlea. The graph B shows those obtained for the angle between the borders of these parts.

It will be observed that the figures in A are more regular and that the extremes are less divergent. I take this as an indication that the measurement between the axes is subject to fewer disturbing influences and is quite as accurate as the measurement between the borders, probably...
more so.

The measurement between the axes is infinitely easier to carry out and was used when measuring the angle in 34 Leeds tali. The resulting figures are shown below in comparison with the corresponding figures for the Australian bones.

<table>
<thead>
<tr>
<th></th>
<th>AUSTRALIAN</th>
<th>LEEDS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>25.4°</td>
<td>17.9°</td>
</tr>
<tr>
<td>Maximum</td>
<td>37°</td>
<td>23°</td>
</tr>
<tr>
<td>Minimum</td>
<td>11°</td>
<td>7°</td>
</tr>
<tr>
<td>No. of bones</td>
<td>163 (55 pairs)</td>
<td>91 (mostly unpaired)</td>
</tr>
</tbody>
</table>

The larger average angle as measured between the axes is accounted for mainly by the fact that the axis of the trochlea is directed more laterally at its anterior end than is the medial border of the trochlea.

In any case, the angle of the neck of the Australian talus is large. Klaatsch (1902, p. 143) mentioned this in 1902 and Poniatowski gives the average angle of 6 Australian tali as 23.2° compared with 25.4° obtained by a similar method for the Ramsay Smith Collection.

Parker and Shattock gave the average figure for the talus of modern civilised races as 10°-12°. Scouler gave it as 13.98° for 23 adults: his figures vary from 0° to 24°.

Volkov, measuring the angle between "l'axe de la téte" and the axis of the trochlea, gave the average angle of the neck of the European talus as 17.3° for the male and 17.7° for the female.

Poniatowski, measuring between the axes of the neck and of the trochlea, found the average angle for 23 German tali to be 22.32°.

Aitken, using a similar method, gives figures which work out as an average of 17.7° for 68 loose tali from the New School of Medicine, Edinburgh.

The angle of the neck of the talus varies with the age of the individual. Asby (2) showed in 1973 that the angle in the new-born child lay midway between those of the adult and of the gorilla, and the combined figures of Scouler and Parker & Shattock give a mean angle of 35.73° for 22 foetal bones as compared with 13.32° for 13 adults. Two of
Sudder's tali were taken from aged adults and for them the angle of the neck was 0°; the lateral border of the neck was parallel to the medial border of the trochlea.

In primitive races the inclination of the neck in a horizontal plane is appreciably greater than is the case with modern races.

Poniatowski gives the angle of the Australian and Patagonian tali which he measured as averaging 25 ° 2° and 24° as compared with 20°.82 for the German talus.

Volkov makes the angle for the Meddas 20°, and for the Negro 24°, as compared with 17°.3° for Europeans.

Sewell, measuring in much the same way as Parker and Shattock, found the angle of the neck to be 13° for the Ancient Egyptian: this angle would be greater if measured between the axes of the neck and of the trochlea. The range of variation was large, 7° to 33° with one case of 43°.

Finally, the Australian tali which I have measured have an angle of the neck which is 7°.3° greater than that obtained for the Leeds tali.

Information in regard to prehistoric tali is scanty. Poniatowski measured three palaeolithic tali and found the angle of the neck to be 21°, 23° and 33°. The angle was 24° for one neolithic bone. The Spy cast yields an angle of 20° according to my own measurements.

In the Simiidae the angle of the neck of the talus is large. Sewell gives it as 29° for the adult Chimpanzee and 35° for the adult Orang. The average of Volkov's figures for six different species of monkey is 35.7°, while his figures for the Anthropoïdes are: Gorilla 30°, Orang 33°, Chimpanzee 35°, Gibbon 36°.

In cases of club foot with varus deformity the angle is very large. Parker and Shattock give the following figures:-

Chili, 18 Mths.; Double congen. varus 33°
Postus, 7 Mths., Marked left varus 31°
Postus, 7 Mths., Extremes left varus 31°
Postus, at term, Extreme bilat. varus 53°
Postus, 3 Mths., Right talipes calcane 33°
Chili, 7½ Mths., Right talipes calcane. 39°

Sudder gives the mean angle of two varus cases as 30°.5°.
It is difficult to know what is the usually accepted figure for the average angle of the neck in modern civilised races. Piersol (13) quotes Scudder's figure, and Bryce (7) appears to quote either Parker and Shattock or Sewall: Sewall does not state his authority for the figure which he gives, or whether it is based on measurements made by himself. Apart from these two, Piersol and Quain, the standard text-books do not make any precise statement as to the average size of the angle of the neck, and the two averages given are distinctly lower than those of Volkov, Aitken and Poniatowski, even when allowance is made for the different method of measurement.

Scudder's average is slightly misleading since he includes in it the two tali from aged adults, each with an angle of 0°. He shows that the angle is very small in old age, but these bones should not be included in a series which is intended to show an average, any more than bones from new-born infants are included.

If these two old bones are excluded from Scudder's series the average angle becomes slightly over 15°, a figure more in accordance with the results for the Leeds tali and with the results obtained by Volkov, Aitken and Poniatowski. Also, on analysis his figures show only 8 bones out of 23, including the two old ones mentioned above, which are under 12°, 10°-12° being the average given by Sewell and by Bryce in Quain's Anatomy.

Aitken (3, p.439) gives measurements of 62 tali from Edinburgh and divides them into two types. Type 1, which he terms the Oriental, possessed extra facets on the upper surface of the neck and prolongations of the medial malleolar facet onto the medial aspect of the neck. They constituted 45% of the series and had an average angle, between the axes of the neck and trochlea, of 21°. Type 2, the remaining 55% of the series, had an average angle of 15°.

The characteristics of type 1 are to a large extent dependent on the angles of the neck in the horizontal and vertical planes, so that what he has done is to classify the bones according to the inclination of the neck. The point which I wish to bring out, however, is that the average angle of the neck in the horizontal plane must have been 17.7°. This figure is similar to the average obtained by Volkov for the European and by myself for the Leeds tali.
and approaches that given by Poniatowski for the German tali which he measured.

I would suggest that the angle of the neck of the talus measured in a horizontal plane is greater than 13° when taken between the borders of the neck and of the trochlea; that it is preferable to measure the angle between the axes of the neck and trochlea, and that the average then lies in the region of 13° for modern civilised races.

Volkov (57) concludes from his examination of a large variety of bones that "l'écartement de la tête astragale de l'axe de cet os est le plus grand chez les grimpeurs et surtout chez ceux dont le pied est prehensible. Dans les races humaines l'angle de cet écartement est le plus grand chez les primitifs et le minime chez les Européens, mais il est très grand chez les Européens nouveau-nés."

The abduction of the first metatarsal demonstrated by Nyman (60) as being present in the 2nd and 3rd months of human foetal life, and confirmed subsequently by Leboucq in 1882 (34a), combined with the presence of an abducted hallux in the apes, has led to the conclusion that the angle of the neck of the talus depends upon the amount of abduction of the hallux. This may be true at least in part and is supported by the presence of a widely separated great toe in savage races.

Hüter (25a) considered the foot of the foetus to be in a position of supination, i.e., inversion, and this was confirmed by Küstner (31) ten years later. A consideration of the foregoing figures, especially in view of the large angle of the neck of the talus present in cases of varus deformity, suggests that the large angle is to be associated primarily with the power of inversion of the foot, and that the abduction of the great toe, which usually accompanies a large angle of the neck of the talus, is not the essential factor. The Simiidae, when walking along a branch of a tree, invert the foot to conform with the slope of the branch on each side. The abduction of the hallux is associated with this and serves to prevent the foot slipping off the rounded surface, but would appear to be a secondary factor in the production of a large angle of the neck of the talus.

A feature which is perhaps insufficiently emphasised
in the current descriptions of the joint movements during inversion of the foot is the amount of movement which takes place between the head of the talus and the navicular bones. There is a sliding movement, combined with slight rotation, between the talus and the calcaneus, and the navicular, along with the cuboid and other bones of the foot, is carried medially on the head of the talus. Any increase in the size of the angle of the neck of the talus must facilitate this movement considerably.

The infant of modern civilised races is born with an angle of 30° or more between the axes of the neck and body of its talus. Dieffenbach (14) wrote as early as 1342 that "All small children have a tendency to club foot... The child retains this as long as it is carried in arms and only gradually loses it on walking when the weight of the body presses the soles of the feet to the ground." The one very young talus among the Australian bones of the Ramsay Smith Collection has an angle of approximately 35°, though it is, unfortunately, too damaged to allow of accurate measurement.

If there are factors in the life or habits of the Australian Aborigine which render the retention of the power of markedly inverting the foot desirable, then this large angle of the neck of the talus will be retained just as it would be retained by a European who adopted similar habits from childhood.

The reason for the retention of a large angle of the neck by the Australian is not far to seek. They habitually adopt a squatting attitude, not with the foot strongly dorsiflexed as in the case of the Punjabi (Thomson, 53a and Havelock Charles, 11), but in an exaggerated sartorial position with the foot tucked under the buttocks in an inverted position. This is well shown in plate 16, p. 32 and plate 22, p. 121 of N.W. Thomas' Natives of Central Australia (32). The first plate shows a group of Arunta warriors squatting in the sartorial position and the second shows the same position adopted at a corroboree. The position adopted is well described by Quarry Wood (39) and he also gives illustrations. There is no need to resort to their occasional tree climbing efforts to explain an adducted great toe to be associated with a large angle of the neck of the talus.
Assuming that the above is correct then it may be possible to explain a large angle of the neck of the talus in hill climbing races by the necessity for frequent inversion of the foot to accommodate it to the surface of the ground.

It may also be added here that to prove that the diminished angle of the neck of the talus in civilised races is hereditary rather than environmental in origin it would be necessary to compare numbers of foetal Australian and foetal European tali with each other.
Axes of the Trochlea

In describing the talus most authors have occasion to refer to the long axis and the transverse axis of both the bone and of the trochlea. The axes of the bone and of the trochlea are usually taken as being coincident. With one exception, Poniatowski, they have, in all the articles which I have consulted, failed to define these axes though using them frequently. The reader is left to infer that the long axis of the trochlea has probably been taken as lying midway between its medial and lateral borders.

In the Australian talus, and in other tali having a large angle of the neck, the medial malleolar facet is prolonged forwards onto the medial aspect of the neck, and there is frequently a triangular prolongation forwards of the adjacent trochlear surface. The result is that the medial border of the trochlea curves medially at its anterior end and, as the lateral border is also curved, the axis of the trochlea must also be curved if taken midway between its two borders.

Poniatowski (45b, p.7) takes the long axis of the trochlea as lying in a vertical plane and fixes its position by means of two points on the surface of the trochlea. These two points are the midpoints, E and F, of two parallel lines, AB and CD, drawn between the two margins of the trochlea, "one in front and one behind", as is indicated in fig. 27. The transverse axis, PP', is drawn by him through the apex of the lateral process and perpendicular
to this sagittal plane, S3'.

Unfortunately, owing to the curvature of the borders of the trophlea, the sagittal plane and the long axis of the trophlea which lies in it will vary in direction according to the position of the two lines AB and CD. In the case of the Australian tali (and most other bones) the anterior end of the line SH will be directed more medially as the line AB is moved further forwards.

In addition, there is frequently a sudden falling away of the medial border at its posterior end. This is specially so in the case of the Australian tali but it also occurs in specimens from the Leeds series. It is illustrated in fig. 28, and I take it that CD would, in such a case, be taken in front of this falling away of the medial border.

[Diagram]

Fig. 28.

I have, when measuring the Australian and Leeds tali, fixed the position of the two lines used in determining the position of the long axis of the trophlea by taking AB at the level of the anterior end of the lateral border, immediately behind the notch for the attachment of the anterior talo-fibular ligament, and the line CD at the level of the posterior end of the medial malleolar facet, immediately in front of the sudden falling away of the medial border of the trophlea if it is present.

These lines are to be taken at right angles to the sagittal plane, since any variation of their direction alters their length and, consequently, the position of their midpoints. This applies more particularly to the anterior line, AB.

It will be seen that the lines AB, CD and S3' are interdependent and that, theoretically, the transverse set of lines cannot be obtained without first having the position of the long axis and vice versa. In practice,
the method adopted was to stretch a thread over the midline of the trochlea as nearly as possible. AB and CD were then taken at right angles to this thread and E and H were marked on the surface of the trochlea. The positions of AB and CD were then checked against the line EH and, if found to be at right angles to it, EH was accepted and the transverse axis marked in at right angles to it by means of another thread stretched across the bone over the apex of the lateral process.

This may appear to be complicated, but is easy to carry out in practice. In two or three cases out of 150 bones it was found that the lines AB and CD were not at right angles to EH as so obtained and the process had to be repeated until the correct position was found by experiment.

The Groove on the Trochlea

An examination of the Ramsay Smith tali reveals several differences between them and the British or European talus as usually described. One of the most striking features of the Australian bones is the depth of the groove which runs antero-posteriorly on the trochlea. Poniatowski designates this the "Mittlereflächskurve" and states that it corresponds with the long axis (EH in fig. 27), that is, lies midway between the borders of the trochlea.

In the case of the Australian tali this groove lies approximately at the junction of the medial and middle thirds of a line drawn between the two borders of the trochlea. An example, No. 123/1 R., is shown in transverse section in fig. 29.

![No. 123/1 R.](image)

Fig. 29, The trochlea and malleolar facets in plane of trans. axis.

The groove divides the trochlea into a larger lateral portion and a smaller medial portion, and the shallower it is, the nearer it's deepest part tends to be to the middle line of the trochlea. The lateral part of the trochlea so marked off is convex, and it tends to be prolonged forwards
so as to give the trochlea a sinuous anterior margin. The groove disappears posteriorly where the inferior transverse ligament is in contact during extension of the ankle joint.

Sewell (13a, p.239), from his examination of the talus of the Ancient Egyptian, distinguished four types of curvature of the trochlea which are shown in fig. 30. He divides these into two main groups:

(a) With a concavity = 80%
(b) Convex laterally = 20%

\[ \begin{align*}
\text{1.} & \quad \text{2.} \\
\text{3.} & \quad \text{4.}
\end{align*} \]

Different types of curvature of trochlear facet. 1 and 2, concave. 3 and 4, concavo-convex.

Fig. 30 (Sewell)

In the case of the Australian talus these two groups constitute the following percentages:

(a) With a concavity = 20%
(b) Convex laterally = 60%
(c) Intermediate or doubtful = 20%

The groove is distinctly narrower in the Australian than in the case with Sewell's illustrations and the medial part of the trochlea is also frequently convex. It is to be noted that Sewell's type 4 has the length of the curve nearer to the medial than to the lateral side, as is the case with the Australian talus.

I have measured the depth of the groove on the trochlea of the Australian talus from tracings of the articular surfaces taken in the plane of the transverse axis. The distance was measured between a line drawn across the highest points on the medial and lateral sides and the bottom of the groove, as indicated in fig. 31.

Fig. 31.
The highest point on the lateral side of the trochlea above the bottom of the groove is frequently some distance from the lateral border of the trochlea; being formed by the summit of the convexity of the larger lateral portion of that surface.

The figures obtained in this manner from 143 bones representing 93 individuals were:

- Average depth = 1.5 mm.
- Maximum depth = 2.5 mm.
- Minimum depth = 0.25 mm.

These figures are given to the nearest 0.1 mm.

Similar measurements were made by means of a modified 'Columbus' gauge for 36 right tali from the Leeds Medical School with the following results:

- Average depth = 1.1 mm.
- Maximum depth = 1.75 mm.
- Minimum depth = 0.0 mm.

The groove on the trochlea of the Australian talus is more obvious to the eye than is the case with the Leeds specimens owing to the more even curvature of the latter. The table below shows the figures for the two series of bones compared in more detail than above:

<table>
<thead>
<tr>
<th>Depth of groove in mm</th>
<th>Leeds specimens</th>
<th>Australian specimens</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 ½ ¾ 1 1½ 1¾ 2 2½</td>
<td>1 0 2 5 10 6 3 4 0</td>
<td>0 1 1 5 19 15 24 14 15 4</td>
</tr>
</tbody>
</table>

Briefly, the trochlea of the Australian talus is more definitely trochlear in form than the Leeds talus used for comparison. The longitudinal groove is more sharply defined and is deeper in the former series of bones and, also, is not usually in the middle line of the trochlea as has been stated for other races, but lies nearer to the medial border. This position of the groove holds good for many of the Leeds tali, but in the majority of cases it lies nearer to the middle line and, in transverse section, presents a more gradual curve occupying a wider area on the trochlea.

The Spy talus conforms more to the latter group, the curve being gradual and the depth of the groove 0.3 mm.
The Borders of the Trochlea

The medial border of the trochlea is commonly stated to be more indefinite and rounded off than the lateral border. This holds good for the Australian talus; so much so that it is at times very difficult to define the position of the border. Fig. 32 illustrates a case in point.

For purposes of measurement some means of determining the position of the borders fairly accurately is desirable, and I have taken them as lying along the maximum convexity of the edge of the trochlea, i.e., on the middle of the curves joining the upper to the medial and lateral articular surfaces.

In the Australian talus the medial border of the trochlea is straight; in its middle part as is stated to be the case for the modern talus described in the standard text-books. Anteriorly, however, it curves gradually away to the medial side owing to the prolongation forwards of the medial malleolar facet and a corresponding prolongation of the trochlea onto the upper surface of the neck.

Posteriorly, there is to be found, in 50% of cases, a sudden falling away of the medial margin; in 25% of cases there is a gradual tailing off and merging of the medial malleolar facet with the posterior border of the trochlea; and in the remaining 25% there are various intermediate stages.

This sudden falling away of the medial margin of the trochlea has already been illustrated in fig. 38 and further examples are shown in fig. 33 (overleaf). It is of importance in measuring the posterior breadth of the trochlea.
Morris (39, p.390) states that the "inner border invariably (extends) further backwaris than the outer" in the European talus. This statement is modified in Buchanan's Manual of Anatomy (10, p.373) to "as a rule it extends farther back than the outer" and is then applicable to the Australian talus in the cases where the medial malleolar facet tails off gradually, i.e., in 25% of cases as exemplified by nos. 204/1 and 233a in fig. 33.

Fig. 33.

In the 50% of cases, similar to nos. 203/1 and 223/B a, where there is a sudden falling away of the medial margin at the posterior end of the malleolar facet, and in many of the intermediate types, the question arises as to what constitutes the posterior end of the medial border of the trochlea. Functionally it is at A, the posterior end of the malleolar facet, for beyond this point the malleolus is not in contact with the margin of the trochlea. In the two specimens illustrated the line A3 represents a distinct
alteration in the curvature of the articular surface and separates the trochlea proper from what is, in effect, a prolongation backwards of the articular surface which appears to have been in contact during extension with the inferior transverse ligament rather than with the tibia. In the majority of the Australian tali, both of this and of the intermediate types, the point C is very definite and, in many cases, is represented by a sharp projection at the posterior end of a pronounced concavity, AC, as illustrated by no. 235/8 a in fig. 33.

The decision as to what constitutes the posterior end of the medial margin of the trochlea is to a great extent a matter of arbitrary description. The posterior end of the malleolar facet may be taken as the posterior end of the margin of the trochlea and, in support of this view, I would suggest that it is the end of the functional medial border. The disadvantage of this method is the extreme variability in position of the point chosen, though the variability is in itself a means of distinguishing between different types of bones. Measurement of the distance between A and C is, however, sufficient indication of varying types.

The point C may be taken instead of the posterior end of the malleolar facet and lies where the medial border becomes continuous with what is definitely the posterior border of the trochlea. In cases where the junction is a curve the point would require to be taken at its maximum convexity.

In the European type of bone the point C is usually situated close to, or coincides with, the posterior end of the medial malleolar facet; it is separated from the end of the facet by a distance of 0.8 mm. or more in 50% of the Australian tali which I have examined, the average distance being 7.75 mm.

I have adopted the latter means of fixing the posterior end of the medial margin of the trochlea, using the point C, since it appears to depart least from the accepted view. The medial margin must then be regarded as consisting of three parts:— an anterior portion corresponding to the forward prolongation of the trochlea which is often present at the medial side, a middle portion and a portion which lies between the posterior end of the medial malleolar facet
and the posterior end of the margin itself.

It is impossible to define the position and extent of the anterior end of the medial margin accurately in many cases. The reason for this is the frequent extension forwards of the medial malleolar facet and the concomitant variation in the shape of the medial part of the anterior border. Fig. 34 illustrates the difficulties met with in this connection.

![Diagram of ankle joint](image)

Fig. 34.

The anterior border of the trochlea has been described as being straight. Morris (39, p.390) states that "The anterior border is straight" when describing the ankle joint, and Sewell (43a, p.233) describes the anterior border of the trochlea of the Ancient Egyptian talus as "usually more or less straight". In many of the standard books such as Cunningham (27), Quain (7), Buchanan (10), Humphrey (24a), Macalister (35), Pestre (51o), Poirier & Charpy (44) and Spalteholz (49) the description given of the talus does not include a description of the anterior border of the trochlea. Piersol (43, p.424) states that "The direction of the anterior border of the articular surface is very uncertain" and describes it as usually projecting forward at the outer end, the rest being either transverse, posteriorly concave or oblique.

Out of 100 tali from the Leeds dissecting rooms less than 50 showed a straight anterior border. The lateral part of the trochlea tends to be prolonged forwards; in the vicinity of the longitudinal groove the anterior edge recedes again, and on the medial side the border may be curved forwards or may recede considerably.
In only 5% of cases among the Australian tali can the anterior border of the trochlea be described as being anything like straight. The lateral portion is, in nearly every instance, curved forwards, or is prolonged onto the neck as a tongue of articular cartilage. The medial part is either sharply curved backwards to form a triangular recess or there is some recession with a triangular area of articular surface filling in the most medial part, or else there is a tongue-like process extending onto the neck.

The posterior border of the trochlea is curved irregularly with the convexity posteriorly and tends to be prolonged further posteriorly on the medial than on the lateral side owing to the presence of the groove for the posterior talo-fibular ligament below the facies intermedia.

The lateral border is curved with the convexity outwards, and in this respect conforms with the accepted description of the European talus. It is limited in front by a well marked impression for the anterior talo-fibular ligament and, posteriorly, it forms the lateral margin of the facies intermedia. It is limited at that end by the groove for the posterior talo-fibular ligament. The curvature of this border as seen from above is, though definitely present in most bones, less than might be expected from a casual inspection. This is partly due to the convexity of the surface of the lateral malleolar facet, and partly to the presence of the facies intermedia.

The Facies Intermedia*

This facet was originally described by Fawcett (17). Sewell (43a, p.239) says of it that it is "always easily distinguishable in the fresh bone, but in the macerated specimen it is not nearly so evident, as it is not marked off in any way from the facet on either side, the superior surface merely passing gradually into the lateral. Occasionally, however, one does, even in the dry bone, get slight indications of its presence".

In the Australian bones, on the other hand, I have found that the surface can usually be made out in bones which are not broken. The thin nature of the surface layer of the bone in this region renders it, as has already been pointed out by Fawcett and Sewell, easily broken or

* The triangular area marked off at the posterior end of the lateral margin of the trochlea by pressure from the posterior tibio-fibular ligament.
Of bones from 112 individuals of the Australian series, 44% were broken in this region. Of the remainder, the medial margin of the facies intermedia could be made out in 60% of cases, and the lateral margin in 73%. Of all the bones, including badly damaged ones, the lateral margin of the facet could be defined in 42% of individuals and could be judged fairly accurately in a good many more.

This amounts to much more than "slight indications" of the presence of the facet, and would suggest that it is more pronounced in the Australian tali than in the Egyptian bones examined by Sewell, and that the posterior talo-fibular ligament was possibly stronger the Australian.

In 16% of the Australian bones there is no indication of any medial margin of the facies intermedia, while the position of the lateral margin is occupied by a distinct continuation of the lateral border of the trochlea, giving the body of the bone a very square appearance.

Sewell distinguishes between the margin of the superior surface and that of the facies articularis superior, and apparently regards the latter surface as being bounded posteriorly by the medial border of the facies intermedia. The boundary of the superior surface, he states, is formed at its posterior end by the "curvature of the facies intermedia". The definition which I have used above for the lateral margin of the trochlea implies regarding the facies intermedia as a part of the trochlear surface which has been modified in shape by the pressure of ligament with a resultant displacement of the lateral margin downwards.

Comparison with the talus of a plantigrade animal, Ursus Maritimus, shows that the lateral malleolar facet does not pass farther back than the apex of the facies intermedia; the facies is situated on the posterior aspect of the trochlea, and its lateral border should be regarded as constituting the lateral margin of the trochlea.
**Subdivisions of the Trochlea**

The trochlear surface may be divided for purposes of description into two main portions, a lateral and a medial, separated by a longitudinal groove. The lateral portion is convex from side to side in over 30% of the Australian tali, but tends to be flatter or even concave in the modern type of bone, and is curved forwards at its anterior margin in practically all the Australian bones. The medial portion is narrower and also tends to be convex in the Australian bones: its anterior end usually forms a triangular area which is continuous with the anterior end of the medial malleolar facet.

In addition to these two main divisions of the trochlea there may be prolongations of the articular surface onto the upper surface of the neck which will be considered later. Also, I would include the facies intermedia as a subdivision of the lateral portion of the trochlea, and there is a further subdivision to be considered which lies medial to and behind the facies intermedia.

This additional subdivision has not, as far as I am aware, been previously described and may be termed the post-trochlear facet. It is separated from the remainder of the trochlea by a change in the antero-posterior curvature of the surface or a groove along a line between the posterior end of the medial malleolar facet and the postero-medial angle of the facies intermedia. Fig. 35 shows a photograph of one of the Australian tali which has this post-trochlear facet to a marked degree.

![Image](image_url)

No. 133/5

Fig. 35, to show the post-trochlear facet.
It will be seen from the tracings of nos. 217/1a and 203/1 in fig. 36 that the area referred to is bounded by the posterior portion of the medial margin of the trochlea medially, by the abovementioned slight groove anteriorly, along the line AB, and by the posterior margin of the trochlea posteriorly.

It will also be seen that the line AB represents the true posterior border of the trochlea and that the area posterior to it is in the nature of a prolongation.

The line of demarcation between the trochlea proper and the post-trochlear facet is very easily seen in most cases where the facet is present, but the groove is not deep. Fig. 37 shows tracings of the trochlea taken longitudinally. Nos. 217/1a and 133/5 show the presence of a distinct groove, while no. 203/1 is an example of straightening out of the curve of the trochlea in the region of the facet. No. 235/3 is a tracing taken close to the facies intermedia where the facet has narrowed down considerably, and no. 133/3 is a tracing of a case where the region of the facet is not marked off by either a
groove or a change of curvature.

This facet is present on the Spy talus. Out of bones from 33 individuals of the Australian series it was found to be definitely marked off in 70% of cases, and in the remaining 30% the line of demarcation was doubtful or absent. In the case of 98 tali from the Leeds dissecting rooms the position was reversed, the groove marking off the facet being absent in 70% of cases and present in 30%. Of this 30% some were well marked as in the Australian bones, but in others the facet was small and reduced to a semi lunar strip or a small projection of the trochlea at its posterior end.

Where the facet is well marked off by a groove it is usually, though not always, associated with a cutting short of the medial malleolar facet at a distance of ½-1cm. from the posterior end of the medial margin of the trochlea. Where the tail of the malleolar facet is pronounced and passes far back there is no indication of a post-trochlear facet.

The impression conveyed by the appearance of a talus with a well marked post-trochlear facet is that the medial malleolus must have been placed further forward (in relation to the lateral malleolus) than is the case in the modern civilised type of foot; that the ligaments in the region of the posterior border of the lower end of the tibia are consequently more oblique, and that these ligaments or the border of the tibia come into contact with and mark off the postero-medial part of the trochlea.
The Length of the Trochlea

Measurement of the length of the trochlea was used by Testut (51a, p.213) during his investigation of the Chancelade remains but he gave no definition.

Volkov (57, p.333) measured "la longueur de la poulie du bord postérieur de celle-ci jusqu'au bord antérieur, en projection et dans l'axe avec le compas glissière". By "en projection" he meant a measurement along the line AB, as shown in fig. 33, and not along the line CD as might be supposed.

Similarly, Adachi (1, p.313) measured "die directe Distanz vom hinteren Ende der Facies bis zur Mitte ihrer vordem Grenze", while Gorjanović-Kramberger (20, p.244) took the "Länge der Trochlea, mittlere vom vorn nach hinten!"

Mollison (33, p.579), on the other hand, took "en projection" literally and measured a line drawn between the middle points of the anterior borders projected onto the basal plane, i.e., along CD in fig. 33.

Poniatowski (45p, p.7) measured the distance between the points of intersection of the "mittlerslängskurve" with the anterior and posterior edges of the superior articular surface.

It will be seen that the methods used for measuring the length of the trochlea fall into two main groups. In the one group the midpoints of the of the anterior and posterior borders are used, while in the other group the points where the long axis cuts the borders are used. Poniatowski's method belongs, in effect, to the latter group, since he states that, in the bones which he examined, the long axis corresponded with the "mittlerslängskurve".

In the case of the Australian talus the use of the midpoints of the borders was found to be inapplicable on
account of the great variability in the shape of the anterior border. Only in $\frac{3}{4}$ of cases is the anterior border approximately straight and the midpoint is difficult to define and variable in position.

![Diagram of trochea](image)

Fig. 39, The anterior border of the trochlea (Australian).

Fig. 39 shows tracings of the anterior borders of three of the Australian tali and illustrates the difficulty of working from a midpoint on the border.

An attempt was made to solve the difficulty by taking an arbitrary anterior border through the anterior end of the lateral margin and parallel to the transverse axis, and by using the midpoints of lines joining the anterior ends and the posterior ends of the lateral and medial borders. Both these methods were soon discarded as being cumbersome and unnecessary, as well as not being comparable with the methods used by other authors.

Another method, that of measuring the length of the trochlea from the anterior to the posterior end of the lateral margin, was also discarded at an early stage because of the inaccuracies introduced by the presence of the facies intermedia and by the frequency of slight damage at both ends of the margin.

In obtaining figures for the Australian bones, and for a number of Leeds specimens for purposes of comparison, three ways of obtaining the length of the trochlea were worked out.

In the first, Volkov's method was used, and the distance was measured between the points where the long axis cut the anterior and posterior margins of the trochlea.

In the second, Poniatowski's definition was adopted, and the distance between the anterior and posterior margins was measured along the line of the longitudinal groove on the trochlea.

In the third, the distance was measured between two lines drawn parallel to the transverse axis of the bone.
and through the foremost and hindmost parts of the anterior and posterior borders respectively. This is easily done by using a pair of calipers with narrow straight blades, the edges of which form the necessary parallel lines, and by applying them with the blades held parallel to the axis.

The facets present on the dorsum of the neck in so many of the Australian bones were not included in this measurement. When a facet is present it is usually possible to distinguish a line which indicates the true anterior margin of the trochlea, but in about $\frac{3}{4}$ of cases this was found to be impossible and no measurement could be made by this method.

The results of measurement of the length of the trochlea along the line of the axis and along the groove on the upper surface proved to be very similar, though the averages are slightly larger when the measurement is made along the line of the axis. The figures obtained are shown below:

<table>
<thead>
<tr>
<th></th>
<th>AUSTRALIAN</th>
<th>LEEDS D.R.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Along Axis</td>
<td>Along Sulcus</td>
</tr>
<tr>
<td>Length of the Trochlea</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>29.9mm.</td>
<td>33,3mm.</td>
</tr>
<tr>
<td>Maximum</td>
<td>34,1mm.</td>
<td>34,4mm.</td>
</tr>
<tr>
<td>Minimum</td>
<td>24,0mm.</td>
<td>23.5mm.</td>
</tr>
<tr>
<td>No. of Bones Measured</td>
<td>96</td>
<td>100</td>
</tr>
<tr>
<td>No. of Individuals</td>
<td>73</td>
<td>72</td>
</tr>
</tbody>
</table>

The reason for the similarity of the results obtained by the two different methods is that the recession of the anterior margin in the region of the anterior end of the sulcus is counterbalanced by the projection backwards of the post-trochlear facet at the posterior end of the groove.

It will be seen that the Australian tali have shorter trochleae than the specimens from the Leeds dissecting rooms, but these figures, since they are absolute, are of little value except as a further indication of the smaller size of the Australian compared with the Leeds tali, and as a means of comparing the two methods of measuring the length of the trochlea. It would seem to be immaterial which of the two methods is adopted. The Spy cast has a trochlear length of 33mm., nearly equal to the measurement of the largest of the Leeds specimens.
When the length of the trochlea is measured by the third method mentioned above the results are naturally larger, but are again similar. This measurement may be termed the total length of the trochlea and the figures obtained from 97 Australian bones representing 74 individuals and 25 unpaired Leeds bones are as follows:-

<table>
<thead>
<tr>
<th>Total Length of Trochlea</th>
<th>AUSTRALIAN TALI</th>
<th>LEEDS TALI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>33.3 mm.</td>
<td>36.3 mm.</td>
</tr>
<tr>
<td>Maximum</td>
<td>33 mm.</td>
<td>41.5 mm.</td>
</tr>
<tr>
<td>Minimum</td>
<td>26 mm.</td>
<td>33 mm.</td>
</tr>
</tbody>
</table>

The cast of the Spy talus in my possession has a total trochlear length of about 41mm., but the extent of the trochlea posteriorly is a little indefinite.

The Relative Length of the Trochlea

The above figures, as already mentioned, are absolute and not in themselves of much value, but the length of the trochlea relative to the length of the bone suggests that the trochlea of the Leeds tali is proportionately as well as absolutely longer than that of the Australian tali.

The relative length has here been taken as the length of the trochlea in its axis expressed as a percentage of the length of the bone. Figures calculated in this way from measurements of 94 Australian bones comprising 73 individuals and 25 unpaired Leeds bones were found to be as follows:-

<table>
<thead>
<tr>
<th>Relative Length of Trochlea</th>
<th>AUSTRALIAN TALI</th>
<th>LEEDS TALI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>61.7</td>
<td>83</td>
</tr>
<tr>
<td>Maximum</td>
<td>69</td>
<td>87</td>
</tr>
<tr>
<td>Minimum</td>
<td>54</td>
<td>57</td>
</tr>
</tbody>
</table>

The Spy talus has a relative trochlear length of about 69. Results obtained when using the length of the trochlea measured along the line of the longitudinal sulcus instead of the line of the long axis are about 0.3 smaller.

Poniatowski (43b, p.3) obtained similar results, but the number of bones measured by him was small and the difference between his Australian and modern bones appears to have been exaggerated thereby. His average for 6 Australian tali is 53.3 and for 5 Patagonian tali is 57, while 24 Pyrolean and 24 German bones gave averages of 65.33 and 65.35 respectively.
With regard to the Anthropoids, Volkov (57, p.635) states that "Chez les Anthropoides la plus courte poulie appartient naturellement à l'Orang; après lui viennent les Gibbons. Le Chimpanzée a la poulie plus long et le Gorille encore plus". In his summary Volkov says "La poulie de cet os est plus courte chez les grimpeurs et la plus longue, parmi les races humaines, chez les Européens". Poniatowski obtained similar results, though his figures are again slightly exaggerated:

- Orangs 53,3
- Gibbons 61,64
- Chimpanzees 63
- Gorillas 63,6

We thus have the same grouping as was found in the case of the length-width index of the bone as a whole. The Gorilla and the Chimpanzee have a broad talus and a relatively long trochlea, on the one hand, and the Gibbon and Orang have a narrow talus and a relatively short trochlea, on the other.

The parallel holds good for the human races. The more primitive types such as the Australian and the Patagonian possess broad talus with relatively short trochlea, while the modern civilised talus is narrower and has a longer trochlea, both relatively and absolutely.

If, however, the total length of the trochlea is used in calculating its relative length, the difference between the Australian and Leeds talus becomes negligible. The figures obtained by this method of calculation are:

<table>
<thead>
<tr>
<th>Relative Total Length of Trochlea</th>
<th>AUSTRALIAN</th>
<th>LEEDS</th>
<th>D.R.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>63,2</td>
<td>63,6</td>
<td></td>
</tr>
<tr>
<td>Maximum</td>
<td>75,5</td>
<td>73,9</td>
<td></td>
</tr>
<tr>
<td>Minimum</td>
<td>61,5</td>
<td>60,4</td>
<td></td>
</tr>
</tbody>
</table>

The main grouping is, in each case, between 65 and 72. For the 3py cast the corresponding figure is 74.

The increase in relative length obtained on using the total length instead of the length in the axis of the trochlea is, expressed as a percentage of the length in the axis, 10,5% for the Australian talus, 8,9% for the Leeds specimens and 7,3% for the 3py cast.
The Breadth of the Trochlea

The breadth of the trochlea has been measured by several authors, some of whom deal more particularly with the difference between the anterior and posterior breadths. These latter measurements will be considered below in a separate section.

Humphry (240, p.335) states that in the Chimpanzee the upper articular surface of the astragalus is less broad, flat and square than in Man, but he gives no measurements.

Aisachi (1, p.313), when measuring the Japanese talus, took as the breadth the greatest distance between the lateral and medial malleolar facets measured on the upper edges, while Jorjanović-Kramberger (20, p.241), when measuring the Krapina talus, took the breadth of the trochlea "in der mitte".

Appleton (5, p.123) measured the breadth "at the level of the hinder end of the auricular facet".

Poniatowski (150, p.7) measured the distance between the lateral and medial edges of the trochlea in the transverse plane.

Volkov (57, tabs. 35 & 36) has measured the combined breadth of the trochlea and the two malleolar facets "en projection" and it is possible to calculate the approximate breadth of the trochlea from this since he also gives the maximum projection of the medial and lateral facets. He measured, in addition, the anterior and posterior breadths of the trochlea.

Owing to the variation of the breadth of the trochlea at different levels, it is necessary to fix definitely the line along which the breadth is to be measured if reliable results are to be obtained. I have, accordingly, adopted Poniatowski's method and have measured the breadth of the trochlea between the two borders as previously defined and in a vertical plane passing through the transverse axis of the bone.

The rounding of the edges of the trochlea of some of the Australian tali and the difficulty of defining the position of the edge accurately rendered it necessary to repeat the measurement. In such cases the average of three measurements was used.

128 Australian tali, representing 33 individuals, were measured and compared with 31 unpaired Leeds bones.
The results of these measurements are shown below:

<table>
<thead>
<tr>
<th>Breadth of Trochlea</th>
<th>AUSTRALIAN TALUS</th>
<th>LEEDS TALUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>27mm.</td>
<td>23.3mm.</td>
</tr>
<tr>
<td>Maximum</td>
<td>32mm.</td>
<td>31.4mm.</td>
</tr>
<tr>
<td>Minimum</td>
<td>22mm.</td>
<td>21.4mm.</td>
</tr>
</tbody>
</table>

Only one of the Leeds bones, however measured less than 23mm., while the Australian bones were fairly evenly distributed between 22mm. and 32mm. with a gradual rise in the numbers from the minimum to the average, and a gradual fall in the numbers as the maximum was approached.

The corresponding measurement for the 3py talus is 31.5mm.

The breadth of the trochlea is greater in the Leeds specimens than in the Australian ones, as was the case with the length of the trochlea, and the 3py cast has a broad trochlea which is, however, within the limits of the measurements of the Leeds, and, in this case, also the Australian bones.

The Relative Breadth of the Trochlea

The only figures on the relative breadth of the trochlea which I have been able to trace are those given by Poniatowski (15p. p.9) from his own measurements and the corresponding figures which he has worked out from the data given by Volkov (37, tables 33 & 39).

His own figures are calculated from the breadth of the trochlea multiplied by 100 and divided by the breadth of the bone. Those taken from Volkov are worked out in accordance with the formula:

Approximate Relative Breadth = 100 - (a x 100 + b x 100),

where
- \( a \) = Maximum projection of the lateral malleolar facet,
- \( b \) = Maximum projection of the medial malleolar facet,
- \( c \) = Breadth of the talus.
The tables given below show the figures worked out by Poniatowski for the relative breadth of the trochlea.

<table>
<thead>
<tr>
<th>No. of Race or Relative Bones Species</th>
<th>No. of Race or Relative Bones Species</th>
<th>No. of Race or Relative Bones Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gorilla 51.7</td>
<td>Gorilla M. 49.2</td>
<td>Chimpan. M. 51.3</td>
</tr>
<tr>
<td>Ziboon 52.92</td>
<td>Gibbon M. 53.1</td>
<td>Orang 64.6</td>
</tr>
<tr>
<td>Patagon. 63.2</td>
<td>&quot;Negrito&quot; M. 52.0</td>
<td>&quot;Negrito&quot; F. 55.5</td>
</tr>
<tr>
<td>Austral. 63.0</td>
<td>Polynes. M. 53.4</td>
<td>Melanes. M. 63.7</td>
</tr>
<tr>
<td>Maori 68.2</td>
<td>Melanes. F. 63.3</td>
<td>Tibetan 63.6</td>
</tr>
<tr>
<td>Burmese 53.1</td>
<td>German 63.05</td>
<td>Japs. M. 53.3</td>
</tr>
<tr>
<td>Tibetan 63.6</td>
<td>Tyroln. 69.23</td>
<td>Peruv. M. 57.0</td>
</tr>
<tr>
<td>German 63.05</td>
<td></td>
<td>&quot;Negres&quot; M. 67.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&quot;Europ. M. 63.3</td>
</tr>
</tbody>
</table>

A. Relative Breadth of the Trochlea (Poniatowski)

A shows the figures obtained from Poniatowski's own measurements and B shows those calculated from Volkov's tables. The slightly lower values in B are attributed by Poniatowski to the difference in the methods of obtaining the figures. He states that it follows from the above that (1) primitives have a relatively small facies articularis superior and (2) the malleolar surfaces are better developed than in the higher races. He adds that the greater relative breadth in the higher races corresponds with the greater stability of the ankle joint combined with reduced flexibility.

These statements may be correct but are not justified by the figures given.

The figures in A must depend upon the factors which govern the breadth of the bone and in the Gorilla, for example, the prominences and irregularities on the non-articular parts play a large part in increasing the breadth and thereby reducing the relative breadth of the trochlea. The same is true, though to a smaller extent, of the Australian tali, and the ridges on the medial surface tend to be more prominent in the lower races which therefore
tend to have a smaller relative breadth of trochlea.

The angle at which the medial malleolar facet is set to the body of the bone will affect the figures as calculated for table 8 and the hollowing of the facet which is described as characteristic of the simian talus, and is also a feature of the Australian talus, will increase the breadth of the articular surface as seen in projection, and thereby reduce the relative breadth of the trochlea without any necessary alteration in the relation of the size of the articular surfaces to each other.

The amount of projection of the lateral process will also have considerable effect on the relative breadth of the trochlea, decreasing it in the lower races.

The breadth of the talus does not seem to me to be a good standard with which to compare the breadth of the trochlea.

The average relative trochlear breadth of the Ramsay Smith Australian talus, calculated for purposes of comparison in the same way as was done by Poniatowski, is 63.7 for 91 bones representing 63 individuals. The addition of measurements from 14 other bones, of which the transverse axis had to be estimated by eye owing to damage to other parts of the bone, makes the average relative breadth 70 for 105 bones representing 79 individuals. The range of variation is from 62 to 32 and the distribution of the various sizes of index is shown compared with Poniatowski's results in fig. 40.

The relative breadth index of the Ramsay Smith bones will be seen to be considerably larger than the corresponding figures taken from Poniatowski.
The size of the articular surfaces of the Australian talus as seen in projection is naturally slightly smaller than the total breadth of the bone: the average, calculated from measurements taken from tracings of the articular surfaces in the plane of the transverse axis, is 37.3 mm. for 118 bones representing 31 individuals.

The breadth of the trochlea relative to this measurement is, therefore, still larger than the averages given by Poniatowski, i.e., about 73 as compared with 70 when the breadth of the bone is used and with Poniatowski's figure of 68.

Further, the average breadth of the trochlea relative to the length of the bone is 71.5 for 29 unpaired tali taken from the Leeds dissecting rooms, as compared with 70 for the Australian bones measured in the same way and with 69 which is the figure given by Poniatowski for his German and Tyrolean bones. The range of variation in the Leeds series is from 65 to 81.

It might be said from the above that the modern talus, as represented by the Leeds bones, has a slightly broader trochlea than the Australian talus, but the difference is slight and the amount of overlapping is considerable, while the amount of variation within one race is sufficient to render the index of doubtful value unless very large numbers of bones are used in obtaining the figures.

Poniatowski states that the relative breadth of the trochlea is important in that it indicates the distribution of the articular area on the upper surface and sides. I disagree with this statement for the following reasons. The presence of a ridge on the medial surface involves, in many cases, an addition of about 2 mm. to the breadth of the bones. If this 2 mm. be subtracted from the breadth of an average Australian talus, and the result divided into the breadth of the trochlea \times 100 so as to obtain a relative breadth, then the difference produced by using a breadth diminished by 2 mm., instead of an average breadth, is 6.6, the indices in question being 83.4 and 75. The ridge in question is frequently absent or poorly marked in the Leeds bones. Thus, the irregularities on the surface of the bones may be sufficient to account for considerable differences between the indices of different races.

The amount of projection of the lateral process is an
additional factor and the realative breadth of the trochlea calculated in this way is, therefore, of little value as an indication of the breadth of the trochlea. It indicates, rather, variations in the shape of the body of the bone which may cancel each other out or be added to each other in different bones, and which can be measured separately and thereby more accurately if desired.

**Breadth of the Trochlea relative to the Length of the Talus**

Owing to the large difference between the figures obtained here for the relative breadth of the trochlea of the Australian talus and those obtained by Poniatowski, it was considered advisable to devise some other index of the breadth of the trochlea.

Figures were accordingly worked out to show the breadth of the trochlea relative to the length of the bone. These are shown below in Fig. 41. The averages were found to be 54.9 for 97 Australian tali representing 74 individuals and 53.6 for 27 unpaired Leeds bones.

![Diagram showing breadth of trochlea relative to length of talus](image)

In the first place, the length of the bone being subject to fewer disturbing factors than the breadth, the range of variation is reduced for both the Leeds and the Australian bones.

In the second place, there is again very little to choose between the average index for the Australian and that of the Leeds tali. Actually, the position is now reversed and the index of the modern talus is less than that of the Australian specimens. This may possibly be
due in part to a shortness of the Australian talus compared with the Leels talus, but there is no justification here for the statement that the trochlea of the Australian talus is narrower than that of modern civilised races. This is supported by an inspection of the Australian talus; the trochlea of most of them appears broad and well developed in proportion to the size of the bone.

The Length-Breadth Index of the Trochlea

This index is the breadth of the trochlea expressed as a percentage of its length, but, as in the case of the relative breadth of the trochlea, figures are scanty in the literature which I have had the opportunity of consulting.

Jewell (48) does not refer to the shape of the trochlea except in regard to the anterior and posterior breadths and the curvature from side to side.

Fraipont (19) does not give figures for the Spy talus, though Poniatowski refers to his illustration as evidence of the breadth of the trochlea, and Leboucq (94c) refers to the broad trochlea of the Spy cast in his possession.

Jorjanović-Kramberger (20, p.214) gives the length of the trochlea of the Krapina talus as 33mm. and the breadth as 23mm., making the length-breadth index 93.

Poniatowski (13b, p.30) gives figures for 3 Palaeolithic tali and one Neolithic (fem.), the indices being 83, 87 and 90 for the former and 90 for the latter. He also gives the figures shown in the table below:

<table>
<thead>
<tr>
<th>No. of</th>
<th>Race or</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bone</td>
<td>Species</td>
<td>L-B. Index</td>
</tr>
<tr>
<td>11</td>
<td>Sibbon</td>
<td>83,3</td>
</tr>
<tr>
<td>1</td>
<td>Gorilla</td>
<td>75,3</td>
</tr>
<tr>
<td>5</td>
<td>Orang</td>
<td>90,2</td>
</tr>
<tr>
<td>6</td>
<td>Maori</td>
<td>95,3</td>
</tr>
<tr>
<td>24</td>
<td>Tyrolean</td>
<td>83,92</td>
</tr>
<tr>
<td>22</td>
<td>German</td>
<td>85,93</td>
</tr>
<tr>
<td>7</td>
<td>Tibetan</td>
<td>97,3</td>
</tr>
<tr>
<td>6</td>
<td>Australian</td>
<td>99,3</td>
</tr>
<tr>
<td>3</td>
<td>Patagonian</td>
<td>90,9</td>
</tr>
</tbody>
</table>

He concludes that the larger indices are primitive and that the smaller indices are progressive and also remarks
that the Orang approaches Man.

Humphry (31, p.258) says that the trochlea of the talus of the Chimpanzee is "less broad, flat and square" than in Man, i.e., probably has a lower length-breath index, but he gives no measurements.

Volkov (37) concluded that the trochlea is short in the climbing animals and, in the human races, longest in the European.

I have worked out the trochlear length-breath indices of the Australian and Leeds talus in two ways. The two sets of figures are based on the breadth expressed as a percentage of the length of the trochlea measured along the line of its long axis and as a percentage of the length measured along the line of the longitudinal sulcus.

The results obtained by these two methods of calculating the index are shown in the table below:

<table>
<thead>
<tr>
<th>AUSTRALIAN TALI</th>
<th>From length measured along axis along sulcus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average L-B Index of Trochlea</td>
<td>39</td>
</tr>
<tr>
<td>Maximum L-B Index of Trochlea</td>
<td>99</td>
</tr>
<tr>
<td>Minimum L-B Index of Trochlea</td>
<td>77</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LEEDS D.R. TALI</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Average L-B Index of Trochlea</td>
<td>85.8</td>
</tr>
<tr>
<td>Maximum L-B Index of Trochlea</td>
<td>98</td>
</tr>
<tr>
<td>Minimum L-B Index of Trochlea</td>
<td>75</td>
</tr>
</tbody>
</table>

It would again seem to be of little importance whether the length of the trochlea is measured in its axis or along the line of the sulcus.

The index for the Spy cast is 32-33.

Fig. 42 shows the results from measurement in the axis of the trochlea in greater detail. 95 Australian talus, representing 73 individuals, and 27 unpaired Leeds talus were used.

![Diagram of trochlea length-breath index]

Fig. 42.
There is considerable variation but a distinct
tendency for the Australian indices to be grouped round a
higher level than the Leeds specimens. 32 out of 73 of
the Australian figures reach 30 or more, while only 5 of
the 27 Leeds ones reach this level.

When the average figures are compared with those given
by other authors it is found that the Australian,
Patagonian and Orang are grouped close to 30, while the
German, Pyrolean and Leeds bones are grouped close to 38
along with the figure for a few Pliostan tali. The few
prehistoric bones available are scattered over the range
covered by the human races. The Sibbon and Gorilla are
definitely separated from the remainder.

The cast of the Spy talus has a comparatively low
index which is not what one would have expected from the
statements in the literature. The trochlear breadth
relative to the length of the bone is also comparatively
small, 53, and well within the range of both the Leeds and
Australian figures; but the relative length of the
trochlea, 74, is equivalent to the largest Leeds figure.
The Spy trochlea would, therefore, appear to be only
moderately broad, but distinctly long in proportion to the
size of the bone.

It is difficult to decide exactly what produces the
differences between the trochlear length-breath indices of
different races.

One possible explanation is that the recession of the
anterior border might be responsible, since it appears to
be more pronounced in the Australian than in the Leeds tali.
This is unlikely, however, as the length-breath index
calculated on the basis of the total length of the trochlea
from front to back produces similar results to the above.
The average index obtained in this way is 30.9 for the
Australian and 73.5 for the Leeds tali.

It has already been suggested that the relative breadth
is not unduly large in the Australian and the explanation
of the size of the length-breath index in the Australian
is probably that the trochlea is shorter, not broader, than
that of the European.

This is supported by an examination of other tali, one
of the best of which is that of Ursus Maritimus. The
animal is definitely plantigrade and the trochlea of the
talus is not specially broad in view of the size of the foot and of the animal. The whole tarsus, with the exception of the calcaneus, is, however, shortened and the skeleton of the foot bears a superficial resemblance to that of a hand.*

The talus shares in this shortening with the result that the trochlear length-width index is 112. The groove on the trochlea is very deep (over 5 mm.) and, as in the case of the Australian, is nearer the medial than the lateral border. Posteriorly, there is a hollow with a prolongation backwards of the articular surface which corresponds to the post-trochlear facet described for the Australian talus, and into which the posterior margin of the tibia or its ligamentous coverings must fit during extension of the ankle joint.

The conditions present are an exaggeration of those found in the Australian talus and produce a rather striking resemblance to the trochlea of the humerus, and the shortening of the trochlea appears to be associated with an increased power of flexion and extension. This contention is supported by the presence of accessory facets on the upper surface of the neck of the Australian talus and by the frequency and degree of development of the post-trochlear facet in the same bones. The talus of the bear mentioned above also showed a prolongation of the articular surface onto the dorsum of the neck.

The impression one receives from an examination of a large number of the Australian tali and from comparisons with other tali is that the body of the bone is less filled out in the bones with a short trochlea and a deep groove. The Spy talus is the antithesis of the Australian bones in this respect, the body being well filled out, the trochlea relatively long and the groove shallow.

*Bryce (7, p.223), quoting Lazarus (33), notes that the tarsus is relatively short in the human foetus, but that it begins to grow more rapidly than the rest of the foot after the seventh month.
The Anterior and Posterior breadths of the Trochlea

It is generally recognised that the trochlea of the human talus is narrower behind than in front, but I have been unable to trace the original source of the statement. The fact was recognised by Humphry in 1353.

In such a comprehensive work as Barisieben's Handbuch der Anatomie des Menschen Krause, when describing the talus and its variations, does not mention the narrowing at the posterior end of the trochlea.

The standard modern text-books nearly all state that the trochlea is wider in front than behind, but they give no figures or method of measuring the difference.

Morris (39, p.330) says that the trochlea is "decidedly narrower behind than in front", but gives no measurements.

Humphry (214, p.337) states that "the upper articular surface is one fourth wider in front than behind", but, again, there is no method of measurement given.

Sewell (48a, p.337) gives the proportions for the Ancient Egyptian and the Anthropoids, but he does not say how he measured these; nor does he say whether he measured any human bones other than the Ancient Egyptian ones, or give any references. His figures thereby lose a considerable part of their value when used for purposes of comparison.

Volkov (37, p.833) measured the anterior breadth of the trochlea between its two borders "au niveau du bord antérieur" and the posterior breadth "également, entre les deux borda latéraux parallèlement à l'axe transversal".

Ponialeski does not provide a definition, but in obtaining the long axis he uses the mid point of a line drawn between the two edges in the posterior half of the trochlea and includes the facies intermedia in this measurement, implying that he would include the facies intermedia in the posterior breadth.

The principal difficulty met with when endeavouring to compare such figures as are given by the above authors is the decision as to whether the facies intermedia has been included by them in the posterior breadth and, also, the level at which the measurement has been taken.

The level at which the line of measurement is taken will appreciably affect the results, both in the case of the anterior and of the posterior breadth. The further
forward the measurement is taken the greater will the result be in each case. If the posterior measurement is taken far enough back, it can be reduced to a very small figure.

Sewell gives the following proportions, taking the anterior breadth as unity:

<table>
<thead>
<tr>
<th>Species</th>
<th>Ant. : Post.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gorillas</td>
<td>1 : 0.5</td>
</tr>
<tr>
<td>Chimpanzees</td>
<td>1 : 0.7</td>
</tr>
<tr>
<td>Orang</td>
<td>1 : 0.3</td>
</tr>
<tr>
<td>Man</td>
<td>1 : 0.3 (0.7-0.9)</td>
</tr>
</tbody>
</table>

The figures for Man refer presumably to the Ancient Egyptian.

Volkov takes the anterior breadth as 100 and expresses the posterior breadth as a percentage of it. His results (57, p.391, tabs. 25 & 26) are as follows:

<table>
<thead>
<tr>
<th>Race or Species</th>
<th>No. of Bones</th>
<th>Post. Breadth (Ant. Br. = 100)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIIJA SATYRUS</td>
<td>4</td>
<td>35.3 38.7 107.1</td>
</tr>
<tr>
<td>NYLON</td>
<td>8</td>
<td>33.3 --- 33.3</td>
</tr>
<tr>
<td>TROGLO. NIGR</td>
<td>3</td>
<td>37.2 72.7</td>
</tr>
<tr>
<td>GORILLA</td>
<td>3</td>
<td>37.3 41.7</td>
</tr>
<tr>
<td>PERUVIAN</td>
<td>11</td>
<td>72.7 32.4</td>
</tr>
<tr>
<td>WWEDE</td>
<td>3</td>
<td>77.3 70.3</td>
</tr>
<tr>
<td>MELANGEANIAN</td>
<td>23</td>
<td>75.0 75.4</td>
</tr>
<tr>
<td>AUSTRALIAN</td>
<td>3</td>
<td>74.7 ---</td>
</tr>
<tr>
<td>NEBRO</td>
<td>23</td>
<td>31.0 31.5</td>
</tr>
<tr>
<td>FUEZIAN</td>
<td>4</td>
<td>73.5 73.8</td>
</tr>
<tr>
<td>PATAGONIAN</td>
<td>4</td>
<td>72.0 32.2</td>
</tr>
<tr>
<td>GOURAAXIS</td>
<td>4</td>
<td>73.4 ---</td>
</tr>
<tr>
<td>SQWIMUAUX</td>
<td>3</td>
<td>30.3 30.3</td>
</tr>
<tr>
<td>POLYNESIAN</td>
<td>5</td>
<td>79.4 37.7</td>
</tr>
<tr>
<td>NEZERIO</td>
<td>3</td>
<td>74.7 73.3</td>
</tr>
<tr>
<td>JAPANESE</td>
<td>23</td>
<td>74.3 72.3</td>
</tr>
<tr>
<td>EUROPEAN</td>
<td>25</td>
<td>31.8 31.7</td>
</tr>
</tbody>
</table>

Attempts to measure the Australian trochlea soon showed that Volkov's method could not be applied to many of the bones owing to the extreme variations in the curvature of the anterior border.

Since there are no other definitions available as a guide to what has been done by other authors, I have measured the anterior breadth in what appeared to be the simplest way, along a line drawn from the anterior end of the lateral margin to the medial margin, parallel to the transverse axis. It is necessary to fix the level at which the measurement is made, since the curvature of the of the medial margin at its anterior end increases the breadth of the trochlea of these bones as the line of measurement is moved forwards. The line suggested forms a convenient arbitrary anterior margin of the trochlea.
Measurement of the posterior breadth of the trochlea presents greater difficulties. It seemed reasonable to take this measurement along a line parallel to the transverse axis, as was done by Volkov, but the alternative methods then possible are five in number owing to the shape of the posterior part of the trochlea in the Australian talus. Measurements may be made:

(1) from the posterior end of the medial margin of the trochlea to the outer border of the facies intermedia,

(2) from the same point as in 1 to the medial border of the facies intermedia,

(3) from the posterior end of the lateral margin of the trochlea to its medial margin,

(4) from the posterior end of the medial malleolar facet to the lateral margin of the facies intermedia,

(5) from the same point as in 4 to the medial margin of the facies intermedia.

Of these five methods, the first two were quickly discarded; the first because the posterior end of the medial margin of the trochlea is frequently farther back than that of the lateral margin, making any measurement parallel to the transverse axis impossible; the second because it gives a ridiculously small value to the posterior breadth.

Using method 3—from the posterior end of the lateral margin of the trochlea to its medial margin—the figures obtained show the Australian trochlea to be narrower behind than the Leeds specimens. The ratio of the anterior to the posterior breadth by this method is 100 : 30(70-90) for the Australian and 100 : 38(72-100) for the Leeds bones.

Similarly, using method 4—from the posterior end of the medial malleolar facet to the lateral margin of the facies intermedia—the average ratio for the Australian is 100 : 33(31-93), and, for the Leeds bones, 100 : 32(32-100).

And, again, using method 5—from the posterior end of the medial malleolar facet to the medial border of the facies intermedia—the average ratio is 100 : 73(83-30) for the Australian and 100 : 82(70-90) for the Leeds specimens.

The range of variation of the posterior breadth in each group of figures is indicated in brackets after the figure representing the posterior breadth.
Fig. 43 shows diagrammatically the methods used here when estimating the posterior breadth of the trochlea.

Using method 3, posterior breadth = C2
Using method 4, posterior breadth = C3
Using method 5, posterior breadth = AB

Fig. 43, The Posterior Breadth of the Trochlea

Which of these methods, if any, have been used by Volkov and Sewell it is difficult to say. Possibly Sewell used a compromise between nos. 4 and 5, the measurement being taken to the surface of the facies intermedia in an attempt to get the true lateral margin of the trochlea which is distorted by the pressure of ligament.

Method 4 would seem to be the best means of indicating the narrowing of the trochlea.

Method 5 is largely an index of the size of the facies intermedia.

Method 3 is, in the case of the Australian tali, and also many of the Leeds tali, influenced by the cutting short of the tail of the medial malleolar facet so that the measuring line strikes the margin of the trochlea in the concavity of the portion of it which is behind the facet.

In any case, whichever method is used, the trochlea of the Australian talus is narrower behind than in front, and the difference is more pronounced than in the case of the Leeds tali.

The difference between the two races is, however, not very great and can be accounted for by the medial inclination of the medial margin at its anterior end. It would seem to indicate, not so much that the trochlea of the Australian talus is unusually narrow posteriorly, as that it is broader anteriorly than the Leeds specimens.

The talus of the Gorilla has, on the other hand, a
trochlea which is very narrow at its posterior end and the medial margin has a distorted appearance. The degree of narrowing is such as to suggest a very considerable amount of play during extension of the ankle joint.

The Heights of the Borders of the Trochlea

The height of the trochlea on its medial and lateral sides has previously been measured in two ways. In the first, measurement is taken of the angle between the horizontal and a line drawn across the highest points of the medial and lateral parts of the trochlea. In the second, the actual heights above the basal plane are measured.

It is difficult to be sure of the exact method used by some authors. The word margin or border is employed but it is possible that the heights have been measured to points close to the margins. Adachi (1, p.313) made use of a 30cm. rod laid transversely across the trochlea.

In dealing with the Australian and Leeds talus I have measured both the inclination of the trochlea to the horizontal and the medial and lateral heights.

Measurement of the heights was carried out by placing the bone on a flat glass plate of known thickness, measuring the distance between the highest point on the side of the trochlea concerned and the under surface of the plate with a pair of straight-edged calipers, and then deducting the thickness of the plate. The measurements were made, not to the margins of the trochlea, but to the highest parts of its medial and lateral portions, on each side of the longitudinal sulcus.

The results show a distinct difference between the Australian and Leeds bones, and were as follows:-

AUSTRALIAN TALI (36 bones = 80 individuals)

Average Medial Height = 27.3 (21.3 - 22.6) mm.
Average Lateral Height = 27.3 (33.5 - 22.6) mm.

LEEDS D.R. TALI (81 bones, mostly unpaired)

Average Medial Height = 31.1 (17.1 - 23.5) mm.
Average Lateral Height = 30.1 (36.3 - 23.0) mm.

The medial side of the Leeds specimens is, therefore, higher than the lateral side. This is contrary to what
one would expect from the statements of Morris, Festut, Humphry and Lazarus (see p.11). The last named author said (33, p.4) that the outer edge of the trochlea is always higher than the inner.

The medial and lateral heights of the Australian trochlea are, on the average, equal to each other.

The heights on the two sides were actually equal only in 1 of the Australian series and in 2 of the Leeds series, but it was found that, for the Australian bones, the lateral side was the higher in 43.3% and the medial side higher in 50%; while, for the Leeds bones, the lateral side proved to be higher in only 23.4% and the medial side in 39.5%.

Taking the result as + when the lateral side is the higher and as - when the medial side is the higher, then the difference between the two sides is practically nil for the Australian (a difference of + 0.03mm. appears when the figures are calculated to the second decimal place) and - 0.32mm. for the Leeds bones.

Also, the range of variation is greater in the Leeds series, being + 1.3 to - 1.9 for the Australian and + 2.3 to - 3.9 for the Leeds specimens.

In order to show the differences between races accurately it is necessary to express the results obtained as an angle or as a proportion of some measurement which has a fairly constant relationship to the size of the bone dealt with. Such a measurement is difficult to find in the talus and, although the length of the bone, the length of the trochlea and the breadth of the trochlea are used in obtaining indices, it would seem preferable to express any result as an angle when this is possible. The use of an angle in this way makes the method applicable to any race or to any species of animal.

Adachi's method of using a rod of fixed length and measuring the difference in the height of its two ends is, in effect, a measurement of the inclination of the trochlea by means of the arc which the angle of inclination subtends. He found the lateral border to be the higher in 7 out of 40 Japanese tali and in two thirds of the European bones which he measured.

Poniatowski measured the angle between the horizontal
and a line drawn across the trochlea, but it is not clear whether he employed the edges of the trochea or its highest points on the medial and lateral sides. He used Mollison's goniometer in carrying out the measurements.

The number of bones measured was too small to indicate more than the difference between Man and the Apes, the conclusion he reached being that the lateral border is always higher than the medial border in the Apes, but that in Man there is no great predominance of either the lateral or medial side.

In view of the results obtained here, however, it is of interest to note that the average angle obtained by Pontatowski for the Patagonian was practically nil, while the average figures for the other races dealt with showed the medial border to be the higher to the extent of 3.1° for the Maori, 2.4° for the Burmese and 0.67° for the Tyrolean.

I have measured the angle referred to above for the same Australian and Leeds bones as were measured for the difference between the lateral and medial heights. The method employed is indicated below in fig. 44, and it is convenient to term the angle so measured the trochleo-basal angle, following the nomenclature used by Appleton (3).

![Fig. 44, The Trochleo-Basal Angle.](image)

The measurement was carried out by placing the bone concerned on a piece of plate glass which had previously been tested for flatness by means of a straight edge. A set square was placed with its edge touching the highest points of the medial and lateral sides of the trochea
and clamped in position. The bone was then removed after verification of the position of the set square and another set square placed alongside the first with its edge on the surface of the glass plate. The angle A3D in fig. 44 then equals the angle between BB produced and the horizontal EF or KL and was measured to the nearest \(\frac{1}{4}\)° by means of a large protractor.

The results obtained in this way proved to be similar to those from the measurements of the medial and lateral heights of the trochlea but the difference between the two races becomes more obvious.

As before, the measurement was considered to be plus when the lateral side was the higher of the two, and the percentage of plus and minus figures naturally remained the same.

The average angle for the Australian tali is 0.8° and the corresponding figure for the Leeds tali is 1.6°. The lateral side of the trochlea is, therefore, lower than the medial side in the case of the Leeds specimens and very slightly higher than the medial side in the case of the Australian.

For the Australian tali, the range of variation is from +5½° to −5°; for the Leeds tali, the range is from +5° to −10½°.

The trochlea of the Australian talus is, for all practical purposes, horizontal on the average and agrees in this respect with the result obtained by Poniatowski for 3 Patagonian bones. The medial side of the trochlea is distinctly low in the Apes, even on casual inspection, and one would therefore expect the modern talus to be high on the medial side if the habitual position of the foot is any guide. The results of measurement of the Leeds tali are in accordance with this expectation, the medial side of the trochlea is distinctly higher above the basal plane on the average than is the lateral side.
THE UPPER SURFACE OF THE NECK OF THE TALUS

General Description

The description of the non-articular portion of the neck of the Ancient Egyptian talus given by Sewell (130, p.74) applies with slight modifications to the Australian talus.

I have not attempted to measure the length of the neck because of the irregularity of the anterior border of the trochlea which makes it almost impossible to fix on any point from which reliable measurements can be made. To judge from an inspection only, the neck would appear to be, if anything, shorter in the Australian talus than in the Leeds bones used for comparison, but there is considerable variation.

The neck is hollowed out in front of the middle part of the trochlea and this area is pierced by, usually, numerous foraminae. In one bone, no. 201/1 R, there is smoothing of the surface in this region but no distinct faceting.

On either side of this hollowed area there is a more or less marked prolongation forwards of the anterior margin of the trochlea and, in front., it is bounded by a ridge usually described as running parallel to the edge of the articular surface of the head.

This ridge is well marked in the Australian and commences at the lateral border of the neck, just behind the articular surface of the head. It may be slightly tuberculated but nothing comparable to the processus trochlearis of Hyrtl was found. In this region it is continuous with another ridge which runs downwards and backwards over the lateral margin of the neck and continues practically parallel to the anterior edge of the lateral malleolar facet. The continuity of the two ridges is, however, frequently rendered indistinct as a result of the lateral faceting of the neck which will be described later.

Traced medially, the ridge on the dorsum of the neck curves slightly forwards and then passes back towards the anterior end of the medial malleolar facet. Here it tends to widen out and become indistinct where it merges with the raised portion of bone which bears the anterior end of the malleolar facet and the forward prolongation of the trochlea which occurs in this region.

In a few bones, however, where the ridge was well
marked, the ridge divided into two distinct limbs as illustrated in fig. 45. The posterior limb passes to the

prolongation of the trochlea or to its junction with the malleolar facet, while the anterior limb approaches the anterior end of the malleolar facet, or else skirts it to become continuous with a similar ridge on the medial surface. This continuity of the ridges on the upper and medial aspects of the bone, occurred in 12 of the Australian series and in 12 of the 35 Leeds tali used for comparison.

The reason for the continuity of the ridges round the anterior end of the malleolar facet is no doubt increased development of the attached ligament in the cases in which it occurs, and the relative infrequency in the Australian, in spite of the generally well marked ridges, may possibly be explained by the prolongation of the malleolar facet forwards which is usually present in that race (see p. 120) Sewell says that the ridges are continuous in only 3% of Ancient Egyptian tali (43b, p. 78).

Articular Facets and Smoothing on the Dorsum of the Neck

Several authors have described articular areas on the upper surface of the neck of the talus. The explanation offered is that they are the result of habitual strong dorsiflexion of the ankle joint.

Thomson (53a, p. 816) described the condition as it occurs on the lateral side of the neck. He divided the development of the facet into three stages:—a preliminary smoothing of the lateral portion of the upper aspect of the
neck, fusion of this smoothing with the articular cartilage of the trochlea and definite faceting. A corresponding facet is found on the margin of the lower end of the tibia and, in such cases, the tibia frequently comes into contact with the ridge on the neck of the talus.

Havelock Charles (11a, pp.1-16) described facets on the neck of the Punjabi talus, finding this lateral one present in 31 cases, doubtful in 6 cases and absent in 13. He also found it to be present in the foetus of that race and it has been shown to be present on the talus of the European foetus.

The 11 Australian tali examined by Thomson showed definite facets in 7 instances and doubtful facets or else smoothing in the remaining 4, while 25 European specimens showed it in only one case.

Quarry Wood (59, p.249) found articular facets on the lateral side of the anterior margin of the lower end of the tibia in 130 out of 336 of the Ramsay Smith Collection of Australian bones.

Among the 150 tali from the same source which were sufficiently intact I have found no trace of faceting or smoothing in 13%, a figure which agrees with those given by Wood for the tibiae. In 15% of cases there was doubtful smoothing and in the remainder, two thirds of the total number of bones, there was either definite faceting or distinct smoothing of the surface on the lateral side.

In 17 of the above tali no line of demarcation could be made out between the margin of the trochlea and the facet, but in the remainder a faint line could be discerned or, in a few cases, a distinct gap was present between the two parts. In a few cases the surface of the trochlea was found to be flush with the neck with no distinct line of separation, but with no evidence of faceting: the border of the tibia must have fitted closely into the hollow as has been described by Thomson (33b, p.214) for the Orang.

Out of 33 Leeds tali lateral smoothing or faceting was found in 18% of cases. The most pronounced form was present in only 4% of cases.
Facets on the medial side of the dorsum of the neck

Parker and Shattock (10) were the first authors to describe a facet which appears on the medial side of the upper aspect of the neck of the talus as a prolongation of the trochlea, and which is continuous with the medial malleolar facet. They stated that it could be found almost without exception in the fetal talus.

Thomson (53b p.213) criticised this description and said that "In some cases there was an extension forward of the inner portion of the superior articular surface, but in no instance did this articulate with the facet on the anterior margin of the inferior articular surface of the tibia, a surface which, in every instance in which it was present, came in contact with the outer border of the neck of the astragalus in extreme flexion of the ankle".

At a later date, Havelock Chariss (11a, p.13) described a medial facet on the neck of the Punjabi talus, occurring in 23 out of 53 bones, and he states that "there may be two facets on the anterior surface of the lower extremity of the tibia, and, corresponding to these, two facets on the upper surface of the astragalus". Also, Sewell (43b, p.73) described a medial facet as occurring in 13% of Egyptian tali and said that in no case was the facet found unaccompanied by a forward prolongation of the medial malleolar facet. He found the same facetting in 13 out of 15 Orangs, 4 out of 6 Chimpanzees and 1 out of 6 Gorillas.

The results of examination of the Australian tali are of special interest in view of the above apparent difference of opinion concerning the facet.

Quarry Wood (53, p.219) describes a facet on the medial side of the anterior margin of the tibia which was present on 2 out of 118 European and on 5 out of 236 Australian tibiae.

When one comes to examine the Australian tali from the same collection of bones the results agree with Wood's findings in regard to percentages.

In 4 of the 150 bones available (nos. 135/3, 209/1, 217/1a and 239) smoothing of the ridge on the neck was found in such a position that a corresponding facet, if present on the tibia, would occupy the medial part of the anterior border of its lower end. In no. 217/1a the smoothing lay wholly to the medial side of the middle line.

*The neighbour of this bone, no. 135/3 L, illustrated in fig. 31, had a considerable degree of smoothing of the ridge, but it scarcely passed
of the trochlea, while a separate facet occupied the lateral side of the neck. In no. 233 the smoothing was less definite and extended towards the lateral end of the ridge, but, owing to the obliquity of the neck, only slightly to the lateral side of the axis of the trochlea. There was no lateral facet in this case. In the remaining two bones the smoothing extended across to the lateral side to join the lateral facet which was also present.

It is perhaps worthy of note that each of these bones was right sided as were two bones selected for close examination as doubtful cases.

This description of the medial smoothing or 'facet' on the neck of the talus does not agree with either the descriptions or the illustrations given by the above authors. There is, however, another facet or prolongation of the trochlea on the medial side of the neck which does correspond to the descriptions given, but which could not produce any smoothing or facetting of the margin of the tibia.

The medial malleolar facet is, in the Australian as in the Punjabi, frequently prolonged onto the neck of the talus and the anterior border recedes in its middle part. The result is that there is, on the medial side, either a triangular non-articular recess, a triangular piece of articular cartilage filling in this area and having a free margin which extends obliquely forwards and medially from the trochlea to the anterior end of the malleolar facet, or else there is a rounded or quadrilateral area of articular cartilage which is always continuous with the medial malleolar facet, but which may or may not be continuous with the trochlea posteriorly.

This area, which is essentially a prolongation of the trochlea on its medial side, has a surface which continues the line of curvature of the trochlea and must therefore come into contact with the under surface of the lower end of the tibia during flexion of the ankle and not with its anterior margin. The area does not correspond to the 'facet' or smoothing on the lateral side of the neck, but to the slight forward prolongation of the trochlea in that region which tends to be continuous with the smoothing or facetting of the neck when it is present.
Fig. 48 shows tracings taken in a longitudinal direction on the lateral and medial sides of the neck and adjacent trochlea. The essential continuity of the medial and lateral prolongations with the trochlea will be seen at once; and the change in direction of the surfaces, both on the lateral and medial sides, where there is smoothing, is also well shown.

Fig. 48

In cases where the medial 'facet' or prolongation is not directly continuous with the trochlea the direction of its surface is still in line with the lines of curvature of the trochlea but with a slight gap intervening.

It will be seen from the foregoing that two 'facets' of essentially different character have been described previously.

No. 1 in fig. 47 is the area described by Parker and Shattock and which must have been in contact with the under surface of the tibia during flexion of the ankle. It also corresponds with the medial facet described by Havelock Charles as occurring in the Punjabi.

No. 2 is the corresponding area on the lateral side.
It is almost invariably present on the Australian talus, but I have not met with any description of it in the literature.

No. 3 is the lateral facet or smoothing which is in contact with the margin of the tibia during flexion of the ankle joint and which was described by Thomson.

No. 4 is the region of smoothing found on the medial side of the neck in four of the Australian tali.

The medial prolongation of the trochlea occurs to a greater or less extent in 75% of the Australian individuals, in 10% the corner of the trochlea passes almost straight across the medial half of the neck to the anterior end of the malleolar facet, and in the remaining 15% there is a non-articular area between the anterior part of the malleolar facet and the medial part of the anterior margin of the trochlea.

The principal cause of the prolongations of the trochlea and of smoothing or facetting of the dorsal aspect of the neck of the talus is, no doubt, habitual adoption of a position of extreme dorsiflexion of the ankle joint, as has already been pointed out by other authors. The prolongations of the trochlea on either side are undoubtedly caused by contact with the under surface of the tibia when it is far forward on the trochlea, the medial one being associated with a forward prolongation of the medial malleolar facet onto the neck. The lateral smoothing of the neck behind the ridge in that region, or of the lateral part of the ridge, is certainly due to pressure from the anterior margin of the tibia during extreme flexion. But the origin of the medial area of smoothing is more open to question.

In order to decide what the conditions are on the medial side of the neck of the Australian talus a number of them were compared with the corresponding tibias from the Ramsay Smith Collection.

Quarry Wood (59, p.256) attributed both the medial and the lateral facets which he described as occurring on the tibias to contact with the neck of the talus, but an examination of corresponding tibias and tali does not support this view.

Although the talus with smoothing on the medial side of the neck did not all have corresponding tibias, sufficient
evidence was obtained to show that the medial side of the neck of the talus does not come into contact with the margin of the tibia during the fullest flexion possible.

In every case where there was lateral smoothing of the neck of the talus the tibia fitted closely against the smooth area in extreme flexion. The medial side of the neck was invariably separated from the margin of the tibia by a distinct interval.

The smoothing of the ridge on the upper surface of the neck, which is usually continuous with the lateral smoothing smoothing, was found to fit closely into a hollow on the margin of the tibia for most of its length in the manner described by Thomson (53a). At its medial end, however, it failed to come into contact with the tibia.

![Fig. 13, No. 332](image)

To take some examples, tibia no. 232, illustrated in fig. 13, had a definite lateral facet on its anterior margin at Y which fitted closely against the smoothing found on the lateral side of the neck of the talus. At the medial side of the tibia a smooth area such as may have been described as a facet was found at X. There is, however, a distinct gap between it and the medial part of the neck of the talus. The ridge, in this case, is prominent and is not smoothed at its medial end.

I am indebted to Mr. J. Borthwick, of Edinburgh University Anatomy Department, for the photographs of the Australian tibias shown here.
Fig. 19 shows the difference between the lateral and medial sides of the same pair of bones as are shown in fig. 13. They have been photographed in a position of full dorsiflexion and the gap between them on the medial side is apparent.

![Fig. 19, no. 232](image1.jpg)

The texture of the bone in the region of the medial smoothing on the tibia differs slightly from that in the region of the lateral smoothing, and is separated from the articular surface on the under aspect of the tibia by a non-articular area.

![Fig. 20, no. 135/3 R.](image2.jpg)

In the case of no. 135/3 R., fig. 20 shows how the medial end of the smoothing on the ridge fails to come into contact with the margin of the tibia. The edges of the smooth area have been outlined with white chalk.
Fig. 51 shows a similar example of the same condition. In this case there was smoothing of the ridge on the neck as shown in the figure. The area marked x is the region which was smoothed but did not come into contact with the tibia.

![Fig. 51, No. 133/3 L.](image)

In the same way, no. 203/1 R., illustrated in fig. 52, had very definite smoothing at the medial side of the neck, but a comparison with the corresponding tibia demonstrated that the neck of the talus could not possibly come into contact with the medial part of the margin of the tibia.

![Fig. 52, No. 203/1 R.](image)

A number of Lees' tali were also examined and, although
there was no sign of smoothing which extended over to the medial side, the conditions present were similar; the lateral part of the neck could be made to meet the margin of the tibia; the medial part of the neck could not be made to do so.

In the absence of the soft parts the explanation of the smoothing towards the medial side of the neck in the Australian is doubtful.

It is possible that the impressions on the bone are formed by the attached ligaments in the same way as the ilio-tibial tract produces a smooth impression on the upper end of the tibia in the Australian (Quarry Wood), but it is difficult to imagine an anterior ligament of the ankle joint which is subject to sufficient strain to produce such impressions on the talus and tibia.

An alternative explanation is that the smoothing may, in some cases at any rate, be caused by pressure from the soft parts which are caught between the two bones during extreme dorsiflexion of the joint.

In addition to extreme flexion of the ankle joint, there are two other factors which may assist in the production of smoothing of the neck of the talus. Sewell has already pointed out that the angle of the neck may influence the production of contact between the tibia and the neck, i.e., a flatter type of bone will have its neck more easily brought into contact with the tibia. Also, the ridge on the neck of the talus is prominent in the Australian and will therefore come more easily into contact with the tibia and so become smoothed.

Fig. 53 (overleaf) is intended to show the variations which occur on the upper aspect of the neck of the Australian talus, but there are so many intermediate stages that it is difficult to give figures concerning the frequency of the different types illustrated. The conditions exemplified by no. 193/2a are probably the most frequent in the Australian.
Fig. 53, Variations on the upper surface of the neck of the tube. Facets or smoothing are shown in outline. The shape of the neck is indicated by a single line. Shaded portions indicate exposed parts.
General Description

Sewell (48a, p.244) has described the medial aspect of the Egyptian talus and, as in the case of the upper surface of the neck, the description applies well to the Australian bone.

Posteriorly and below there is the prominence of the medial tubercle. Above and in front of it there is a rounded impression (for the deltoid ligament) which lies below and, in the Australian, sometimes slightly behind the tail of the malleolar facet. This impression has clearly cut upper and anterior margins but tends to merge with the medial tubercle below and posteriorly.

In front, the medial tubercle passes into a ridge which runs towards the anterior end of the malleolar facet and, in an appreciable number of cases, becomes continuous with the ridge on the upper surface of the neck. In other cases it tends to become indistinct at its anterior end and merges with the slight prominence which bears the anterior part of the malleolar facet.

A triangular and relatively depressed area is thus left, bounded by the malleolar facet above, the ridge below and in front, and the impression for the deltoid ligament below and behind.

Below and in front of the ridge there is another area similar to the above (both of them being perforated by numbers of vascular foraminae), bounded by the ridge above and posteriorly, by the edge of the navicular facet anteriorly and by the usually prominent edge of the middle calcaneal facet below. Above and in front, this area becomes continuous with the upper surface of the neck through a gap of varying width which lies between the navicular facet and the ridge or the anterior end of the malleolar facet.

The special points which emerge from an examination of the Australian tali are the development of the medial tubercle, the prominence of the ridge on the medial surface of the body and the narrowness of the space between the edge of the navicular facet and that of the anterior end of the malleolar facet.

The width of the space between the malleolar and navicular facets will be considered along with the description of the medial malleolar facet.
The prominences of the medial tubercle and of the ridge were found to be more marked in the Australian than in the Leeds bones used for comparison, but it was not found possible to devise any suitable means of proving the point by measuring the degree of prominence in relation to the adjacent surfaces.

![Diagram](image)

Fig. 51 shows the ridge found on the medial surface of the body of the Australian talus.

The Medial Malleolar Facet

This facet passes further forward in the Australian than in the Leeds specimens examined. Inspection shows that the anterior end of the medial malleolar facet of the Leeds bones seldom passes much, if at all, beyond the level of the anterior end of the lateral margin of the trochlea; in the Australian bones it practically always does so to a considerable extent.

This is difficult to demonstrate conclusively by means of measurements owing to variations in the attachment of the anterior talo-fibular ligament and the frequency of slight damage to that region.

The average distance between the anterior end of the malleolar facet and the edge of the articular surface of the head at its nearest point is less in the Australian than in the Leeds bones, the average measurements being 5.7mm. for the former and 3.8mm. for the latter. The measurement depends, however, not only upon the size of the bone and the position of the malleolar facet, but also upon the angle of the neck and the extent of the articular
surface of the head. The angle of the neck, being large in the Australian, tends to approximate the two articular surfaces, and the articular surface of the head will, if it is more extensive than usual, approach the end of the malleolar facet.

In addition, the malleolar facet may be either longer or shorter than is usual, or the facet may be displaced as a whole. Measurements from its anterior edge to its posterior end in a straight line average 25.4mm. in the Australian and 23.2mm. in the Leeds bones, but, expressed as a percentage of the length of the trochlea in its axis, these figures are equivalent to 33.5% and 34% respectively.

The difference is slight, however, 2% of the trochlear length being equivalent to 0.8mm. in the Australian and 0.7mm. in the Average Leeds bone. It should also be remarked that the length of the trochlea in its axis, relative to the length of the bone, is slightly smaller in the Australian, 62 as compared with 63 for the Leeds bones.

That the length of the malleolar facet has not a great amount of influence in determining the amount of forward prolongation is shown by the fact that the posterior end of the facet is also further forward in the Australian than in the Leeds specimens. The average distance between the posterior end of the facet and the posterior end of the medial margin of the trochlea is 7.7mm. for the Australian and 5.9mm. for the Leeds bones, in spite of the smaller average size of the former specimens.

The difference between the two races is greater in the case of the anterior than of the posterior measurements, probably as a result of the additional factors, such as the angle of the neck, mentioned above.

Taking the anterior measurement as 100, the ratios between the anterior and posterior measurements are 100 : 135 for the Australian and 100 : 53 for the Leeds bones. This is a complete reversal of the state of affairs in the two races, and suggests that the malleolar facet is placed distinctly further forward on the Australian than on the Leeds talus.

To sum up, the medial malleolar facet does not pass so far back in the Australian as in the Leeds talus: it is, if anything, slightly longer in relation to the size of the bone in the Australian, and it passes further forward in
that race, so as to occupy part of the medial surface of
the neck. This is facilitated by the larger angle of the
neck in the Australian, as a result of which the medial
malleolus may come into contact more easily with the neck
during extreme flexion of the ankle. The appearance of
forward prolongation is slightly exaggerated by the large
angle which approximates the margin of the articular surfa-
ces of the head to anterior end of the facet. It may
also be slightly exaggerated by the greater extent of the
articular surface of the head which is present in the
Australian bones.

Parker and Shattock (43) originally drew attention to
the prolongation of the articular surfaces onto the medial
and upper surfaces of the neck of the talus, and found it
present "almost without exception in the foetal astragalus".
They explained it by the obliquity of the neck of the bone
in the foetus and the flexed position of the ankle during
intra-uterine life. They also remarked that the condition
persisted in the adult Ape along with the obliquity of the
neck, the capacity for inversion of the foot and the flexed
position of the ankle joint.

Havelock Charles (11) says of the medial malleolar
facet in the Punjabi that "In a well marked bone it passes
as far forwards as to occupy half the inner portion of the
neck". He associated the condition with extreme flexion
during squatting, or extreme adduction of the foot in the
sartorial position.

Sewall (13a) describes this forward prolongation of
the malleolar facet as occurring in the Ancient Egyptian,
but does not give the frequency of occurrence. He states
that it is "a characteristic feature in the Orang and
Chimpanzee" and that he has also found it in the Gorilla.
He also says that it is found in the foetal talus and that
it is related to the inverted position of the foot.

The explanation in Man, foetus and Ape would appear to
be the same in each case:— the power of strong inversion
of the foot, resulting in a large angle of the neck,
combined with dorsiflexion of the ankle joint.

In the Australian, the facet would appear to be placed
far forward, and this suggests the possibility that the
medial malleolus may also be far forward.
The combined effects of the prominence of the ridge on the medial surface of the talus and the prolongation of the medial malleolar facet forwards produce cases of smoothing of the ridge in the same way as occurs on the dorsum of the neck. Ten selected Australian cones showed graduated stages between smoothing of the ridge as the anterior end of the malleolar facet approaches it, fusion of this smoothing with the facet with the line of demarcation still visible and, finally, obliteration of the line of demarcation. The photographs in fig. 53 have been selected to illustrate the conditions found.

Fig. 53

No. 219/2a is a specimen without smoothing, No. 139/3 shows smoothing in front of the facet, No. 139/3b is a specimen in which the dividing line has disappeared and the fossa is similar to intermediate stages.

The fact that these intermediate stages can be traced shows that, in these cases, the condition is acquired.
"Hollowing" of the Medial Malleolar Facet

All the authors mentioned in the previous section have recognised that the prolongation forwards of the medial malleolar facet is associated with a medial curvature of that facet at its anterior end which produces a hollowing in an antero-posterior direction.

This hollowing is noticeable in the foetal talus. In the adult bones from the Leeds dissecting rooms it is occasionally marked, but, as a rule, is not evident and in many cases the facet is almost flat or is even slightly convex. The slight hollowing which is frequently present is often caused rather by lipping at the anterior end of the facet than by a genuine curvature of the facet.

In the Australian the curvature is such that the anterior end of the facet faces upwards, medially and, at its foremost part, slightly backwards. It is well marked in almost all the available bones, 4 out of 33 being flat, while in 13 of the same series the depth of the hollowing is 1,5 mm. or more.

The depth of the hollow was measured by means of the modified 'Columbus' calipers used for measuring the depth of the trochlear sulcus. The horizontal bar of the depth gauge was placed on the most prominent parts of the anterior and posterior ends of the facet and the greatest depth measured in the usual way to the nearest 0,1 mm.

The average depth of the hollowing was found to be 1,4 mm. for the Australian and 0,7 mm. for the Leeds bones. Only 3 of the latter had a depth of 1,5 mm. or more and the number of flat or slightly convex facets was 5 out of 73.

Fig. 53 shows tracings of the medial malleolar facets of six of the Australian tali, taken by means of a periostium along the long axis of the major portion of the facet. The letters A and P denote the anterior and posterior ends of the tracings; the posterior half of the dotted line in front of no. 233a represents the ridge in front of the facet and the depression is due to damage to the bone.
The appearance of convexity at the posterior end of the tracings is due to the fact that the tracings could not be taken along the axis of the facet in its whole length. The convex posterior part of the tracing represents the place where the line of the tracing passes onto the medial border of the trochlea.

The curve of the facet may be an even one, as in no. 240, but more usually the posterior part is only slightly curved, while there is a more pronounced bend in the anterior part, about the junction of the anterior and middle thirds of the facet or slightly in front of that point.

Fig. 37 shows a pair of the Australian tali which have been photographed from behind to illustrate the degree of curvature of the medial malleolar facet.

Quarry Wood (59, p. 254), when describing the tibia of the Australian, says that frequently "The anterior border (of the malleolus) was somewhat everted or bevelled, so that there was an extension of the articular surfaces on to the anterior aspect". He found varying degrees of this condition, but it was "well marked" in 23 specimens.

Fig. 53 illustrates the similarity between the contour of the articular surface of the Australian medial malleolus and that of the corresponding facet on the Australian talus. The beveling on the malleolus obviously corresponds to the
medial inclination of the anterior part of the facet on the talus and is, so far as I can see, secondary to it. It would hardly seem necessary to assume that the bevelling is "to permit the talus to be slightly rotated in the medial direction around a vertical axis" as Quarry Wood suggests. Although such a rotation may take place, the shape of the malleolar facet on the talus is sufficient to account for the bevelling of the malleolus. The two conditions may be caused by a combination of habitual strong dorsiflexion of the ankle joint, a large horizontal angle of the neck and a prominent ridge on the medial surface of the talus, and I find it difficult to see how the curvature of the facet on the talus can be produced by the sartorial position, except indirectly as a result of inversion and the consequent change in the angle of the neck.

Wood also points out that "In other bones, in which there was no facet on the anterior border of the malleolus, the malleolus was markedly oblique, the whole process being bent in the medial direction". He attributed this to the strain, i.e., pressure, on the malleolus resulting from the adoption of the sartorial position. I have been unable to find any conclusive evidence of such pressure on the talus. The shape of the malleolar facet is such in some cases, however, that it would accommodate itself well to such a form of malleolus.

It has already been mentioned that the length of the medial malleolar facet of the Australian talus equals 33% of the axial length of the trochlea, while that of the Leda tali equals 41%. The range of variation is greater in the Australian, being from 106% to 63% compared with a range of from 93% to 74% for the Leda bones.

In the one Australian bone, shown in fig. 59, where the length equalled only 63% of the trochlear length, the
anterior end of the facet reached the level of the anterior end of the lateral margin of the trochlea, as in the usual modern bone. The tail of the facet was short, giving the facet an almost rounded appearance and leaving a distance of slightly over 1 cm. to be occupied by the concave posterior portion of the margin of the trochlea already referred to in the section on the trochlea. Sewell found this condition in 0.7% of his Ancient Egyptian tali.

In three of the Australian bones, where the length of the malleolar facet exceeded that of the trochlea, it was found that the anterior end of the facet was prolonged onto the neck, while the tail of the facet was carried far back as is more usual in the modern type of bone.

Similarly, the shortest relative length of the malleolar facet in the Leeds collection occurred in a bone with a distance of 0.3 cm. between the posterior end of the facet and the posterior end of the trochlear margin, leaving a concave portion of that margin such as is more usual in the Australian tali. The Leeds bone with the shortest relative length of the malleolar facet, 93%, had the facet prolonged onto the neck as is usual in the Australian bones.
The Head of the Talus

The Angle between the Long Axis and the Horizontal

The feature of the head of the talus most frequently referred to is the angle at which the long axis of the articular surface is inclined to the horizontal.

Hüter (25) stated that the navicular facet was horizontal in the foetus and set at an angle of 45° in the adult, while Clarke (12) gave the average angle for 12 foetal talii as 10°.

Asby (2) gave the angle as 12° for the gorilla.

Later, Volkov (57), Sewell (130), Adachi (1), Fraipont (13) and Poniatowski (150) defined methods of measuring the angle and gave measurements for various races.

Sewell measured the angle between the long axis of the head and the transverse plane of the trochlear surface, and Adachi used a similar method.

Volkov and Fraipont both measured the angle between the greatest diameter of the head and the osseal plane, while Poniatowski used what is practically the same method and measured the angle between the "mittlerelängskurve" of the navicular facet and the same plane. The last named author attained his object by fixing a needle in the head in the required direction. He then placed the bone on a glass plate with the needle touching its edge and measured the angle made between the needle and the plate.

Apart from the discrepancies as a result of the difference between the method used by Sewell and Adachi and those used by other authors, the figures available are at variance with each other. For example, the figures given by Poniatowski are lower than those given by Volkov (150, table 20 and 57, tabless 163 & 133). Poniatowski suggests that the differences between his own figures and those of Volkov are due to the latter author having taken into account the upper part of the curve of the head rather than its whole length.

For the new-born child:—Hüter states that the head is horizontal, Clarke gives the angle as 10° and Volkov gives it as 15.5°.

For the adult European:—Poniatowski gives the average figure for 20 German bones as 33.3° and for 21 Tyrolean bones as 35.23°, while Volkov gives the average for the male European as 40° and for the female European as 37°. Hüter's figure for the adult is 15°.
For the gorilla: - Asby gave the angle as being 12°, Volkov gave it as 26.5° and Poniatowski's result was 13.7°.

For the orang: - Sewell found the angle to be 3° in the young animal and 12° in the adult. Poniatowski's result was 3.1° and Volkov's was 23°.

For the ziooon: - Poniatowski and Volkov obtained results of 13° and 21° respectively.

These differences, though possibly due in part to the small number of measurements made for each race or species, can be accounted for to a large extent by the possibility of differences in technique.

In bones which have a small angle of torsion of the head that part is usually oval and has a relatively straight "mittelrelängskurve". In those which have the head considerably tilted this line, besides being curved with the convexity of the head, is also curved with the concavity of the curve towards the upper border of the articular surface. The angle between the axis of the articular surface is greater at the lateral and upper end than at the lower and medial end. Any measurement of the angle of torsion of the head should take into account the whole length of the articular surface. Also, the results obtained must vary considerably according to whether the navicular facet alone is considered or the whole articular surface of the head is used. The results will be lower if the navicular facet alone is used and, if the facets formed by the spring ligament and the tibialis posterior tendon are included, the results will be larger.

The method which I have used to estimate the amount of torsion of the head of the Australian and Leeds tali is similar to the methods used by Fraipont, Volkov and Poniatowski.

A thin cord was stretched over the long axis of the articular surface of the head (as nearly as possible midway between the upper and lower borders), excluding only the calcanean facets, and a pencil mark made on the bone along the line so indicated. The bone was then laid on a flat surface and the angle between the plane in which the pencil mark lay and the plane on which the bone rested was measured by means of a straight edge and a large protractor.

A cast of the 3py talus was measured in this way and found to have an angle of 31°. Later, Fraipont's figure
was ascertained and found to be $30^\circ$. The method would seem to be very similar to that used by him.

70 Australian bones were sufficiently intact for measurement by the above method and were compared with 62 Leeds specimens.

The average angle of torsion proved to be $31^\circ$ for the Australian and $33^\circ$ for the Leeds bones. In each series the angle was below $20^\circ$ in only one case and $10^\circ$ or more in 10% of cases. The maximum angle found among the Leeds bones was $47^\circ$, and among the Australian bones it was $43^\circ$. The minima were $13^\circ$ and $16^\circ$ respectively.

Poniatowski's average, obtained from 5 Australian tali, was $30,2^\circ$.

Sewell states that the angle between the axis of the head and the transverse plane of the trochlear surface is $43,5^\circ$ for the Ancient Egyptian and $41^\circ$ for 35 bones from adults from Borneo. The range of variation in the Ancient Egyptian series was from $25^\circ$ to $62^\circ$.

His illustration (43o, fig.20, p.132) suggests that the high value of the figures obtained may possibly be due to the same cause as was put forward by Poniatowski to explain the difference between his figures and those of Volkov. His results for the Apes and the human foetus appear to have been quoted. In addition, the measurement of the angle to the planes of the trochlea, instead of to the basal plane, will have the effect of altering the result by 2° or 3° in the case of Man and considerably more in the case of the Similae.

No doubt the best planes from which to measure the angle of torsion of the head would be the plane of the axis of rotation of the ankle joint, but this is not feasible. The heights of the borders of the trochlea may, and do, vary independently from the axis of rotation of the joint, and this variation was considered sufficient to justify discarding the method in favour of the use of the basal plane already used for many other measurements of the talus.

The figures quoted above show that the results obtained by different authors are not always comparable, whether as a result of differences in the method of measurement employed, or because of the limited number of bones used. The tables of results given by these authors all tend to show, however, that the angle in question is
smaller in the young than in the old; that it is distinctly small in the Apes, and that it is slightly smaller in certain lower races than in the modern European.

Sewell says that "It is evident, therefore, that during the process of eversion of the foot the line of articulation of the caput tali has been rotated in the manner shown".

Although Sewell's evidence is slender, it would seem that the torsion of the head does vary with the degree of inversion or eversion of the foot, and one would expect this to be the case.

One of the outstanding features of the Australian talus is, however, the amount of inversion of the foot which it has been built, or altered, to permit; and the angle of torsion of the head is only slightly less than in the case of the Leeds bones used for comparison and measured in the same way by the same person.

The length-height index and the vertical angle of the neck of the Australian talus bear a very similar relation to the corresponding results obtained for the Leeds talus and I have already suggested that these two criteria vary according to the degree of development of the long arch of the foot. As far as Sewell's evidence is concerned, it can just as well be said that the torsion of the head varies with the arches of the foot as that it varies with the amount of eversion of the foot.

Since the head of the talus is situated on the medial side of the foot, its lateral border will tend to be higher when the transverse arch of the foot is pronounced than when there is little or no arch present.

One would expect the transverse arch to vary, as a general rule, with the longitudinal arch in its development. The longitudinal arch in the Australian, estimated by the value of the length-height index or by the angle of the neck in a vertical plane, is only slightly less than that of the Leeds specimens. The angle of torsion of the head is also only slightly less in the Australian than in the Leeds bones.

This idea that there is some correlation between the length-height index (selected in preference to the angle of the neck because of the greater accuracy in measurement of the index) and the angle of torsion of the head is borne out by a more detailed examination of the figures available.
The Australian tali were arranged in order of the size of the length-height index and the angle of torsion of the head noted for the bones in each group. The average angles corresponding to each index (taken to the nearest unit) are shown below:

<table>
<thead>
<tr>
<th>Length-height Index</th>
<th>Av. Angle of Torsion</th>
<th>No. of Individuals</th>
</tr>
</thead>
<tbody>
<tr>
<td>51</td>
<td>37,3</td>
<td>5</td>
</tr>
<tr>
<td>53</td>
<td>33,6</td>
<td>3</td>
</tr>
<tr>
<td>55</td>
<td>30,0</td>
<td>9</td>
</tr>
<tr>
<td>57</td>
<td>37,3</td>
<td>5</td>
</tr>
<tr>
<td>53</td>
<td>32,0</td>
<td>4</td>
</tr>
<tr>
<td>59</td>
<td>33,3</td>
<td>1</td>
</tr>
</tbody>
</table>

The number of bones sufficiently intact to yield both the index and the angle is small, but the way in which the angle varies with the index is surprising.

When the angles are plotted out on squared paper with the length-height index as a base line unit the same upward trend of the angle with an increasing index is seen, but this method reveals several exceptions to the rule which are concealed when the averages only are considered.

It has already been noted that the articular surface of the head of the talus is inclined upwards at the lateral side more than at the medial side, and that this is specially the case in bones which have a large amount of torsion of the head. The navicular bone will therefore pass more and more upwards as the foot is everted and the navicular carried laterally and upwards. Marked obliquity of the head of the talus must facilitate a small amount of dorsiflexion at the transverse tarsal joint. This is in accord with the easily made observation that dorsiflexion of the foot is the natural accompaniment of extreme eversion of the foot.

We thus have, in the Simiidae, a lack of development of the arches of the foot, and of power to evert it, combined with a small angle of torsion of the head of the talus. Similar conditions hold good for the European foetus, but, when the adult stage is reached, the arches of the foot are developed, the foot becomes everted from its original position and the degree of torsion of the head of the talus becomes greater. In the lower races the arches of the foot are not so well developed as in the European
and the torsion of the head of the talus would appear to be less marked in the former.

If the degree of inversion or eversion which is habitually adopted is the deciding factor in the absence or presence of torsion of the head of the talus, then one would expect the Australian tali to have only a very slight degree of torsion. This is not the case and the amount of torsion of the head appears to be more in proportion to degree of development of the arches of the foot.

Another factor which may influence the size of the angle of torsion of the head as it has been measured here is the development of the plantar calcaneo-navicular ligament and variation in the size of the facets made on the head by it and the tibialis posterior tenion. If the ligament is well developed and produces a large facet on the head the effect will be to depress the medial end of the line used for estimating the position of the long axis and so increase the size of the angle measured.

Enlarged photograph of three full-time foetal tali

Fig. 69, Comparison between Australian and normal tali, with maxima and minima torsion of the head, and normal foetal tali.
Measurements of the Head of the Talus

Apart from the angle of torsion of the head, I have not been able to trace any articles except that of Poniatowski (156) which give measurements of the head of the talus. Sewell (150) gives a general description of the head of the Ancient Egyptian talus, and he and Fawcett (17) deal with the areas marked off as a result of pressure from the plantar calcaneo-navicular ligament and the tendon of tibialis posterior, Fawcett being the first to describe the one main by the tendon. These descriptions apply in general to the Australian bones.

Humphry (219) states that the head of the talus is almost spherical in the Chimpanzee.

Poniatowski (156, p.19) has worked out the length-breadth index, the length-height index and the length of the head relative to the length of the bone. His results are shown below:

<table>
<thead>
<tr>
<th>Race or Species</th>
<th>No. of Bones</th>
<th>L-B.Index</th>
<th>No. of Bones</th>
<th>L-H.Index</th>
<th>No. of Bones</th>
<th>Rel. Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hylobates</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>11</td>
<td>44.00</td>
</tr>
<tr>
<td>Simia Sat.</td>
<td>5</td>
<td>62,40</td>
<td>4</td>
<td>49,00</td>
<td>5</td>
<td>43.30</td>
</tr>
<tr>
<td>Gorilla</td>
<td>5</td>
<td>62,30</td>
<td>5</td>
<td>51,80</td>
<td>5</td>
<td>53.60</td>
</tr>
<tr>
<td>Australian</td>
<td>6</td>
<td>63,30</td>
<td>6</td>
<td>40,40</td>
<td>6</td>
<td>53.20</td>
</tr>
<tr>
<td>Tibetan</td>
<td>8</td>
<td>63,70</td>
<td>4</td>
<td>31,30</td>
<td>7</td>
<td>53.30</td>
</tr>
<tr>
<td>Patagonian</td>
<td>5</td>
<td>60,00</td>
<td>5</td>
<td>43,40</td>
<td>5</td>
<td>53.80</td>
</tr>
<tr>
<td>Burmese</td>
<td>7</td>
<td>64,10</td>
<td>7</td>
<td>44,30</td>
<td>7</td>
<td>53.60</td>
</tr>
<tr>
<td>Pyrolean</td>
<td>22</td>
<td>61,21</td>
<td>22</td>
<td>39,14</td>
<td>22</td>
<td>51.30</td>
</tr>
<tr>
<td>German</td>
<td>9</td>
<td>34,20</td>
<td>7</td>
<td>43,20</td>
<td>10</td>
<td>32.10</td>
</tr>
<tr>
<td>Maori</td>
<td>3</td>
<td>62,20</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>31.00</td>
</tr>
</tbody>
</table>

In obtaining these figures he measured the greatest length parallel to the upper border and the greatest breadth perpendicular to the length. The height was taken as the distance between a straight line joining the ends of the "middlerslängskurva" and the farthest point of the curve of the articular surface. Owing to the difficulty in distinguishing the line of demarcation between the navicular facet and the facets for the tibialis posterior and the plantar calcaneo-navicular ligament, he included all three facets in the measurement of the length of the head.

He discarded both the length-breadth and length-height
indices when drawing his final conclusions, and pointed out that the Tibetan and Burmese bones have widely differing length-breath indices although they are from nearly related races, and remarked that the length-height indices, though useful for comparison between the Ape and Man, are not so for comparison between different human races.

When measuring the heads of the Australian and Leeds talus, I have taken the length in two ways:— (1) the direct distance between the two ends of the articular surface by means of straight edged calipers and (2) along the articular surface in its long axis by means of a flexible steel tape. These measurements give the long diameter of the facet and the true length along which movement can take place. I have included in these measurements the whole length of the articular surface of the head, excluding only the calcanean facets on its under surface.

The figures so obtained from 73 Australian bones and 77 Leeds bones are as follows:—

Length along the surface of the head,

Average Australian = 41.3 mm.
Average Leeds bone = 47.7 mm.

Direct Length between the ends of the Long Axis,

Average Australian = 39.8 mm.
Average Leeds bone = 33.0 mm.

Using the larger measurement, i.e., the length of the head along its surface, as 100, the average ratios between the two measurements are:—

AUSTRALIAN— Direct Length : Surface Length :: 32.3 : 100
LEEDS— Direct Length : Surface Length :: 63.4 : 100

The proportions for the individual bones range from 33.5 : 100 to 78.5 : 100 for the Australian series and from 61.7 : 100 to 97.1 : 100 for the Leeds series.*

These figures indicate a greater degree of curvature of the head of the Australian talus and this, in turn, indicates a greater range of movement for the surfaces in contact with the head. The rounding of the articular surfaces in the lower races of Man and in the Ape has already been pointed out by other authors in connection with the trochanters.

*It is to be noted that the proportion of the averages of two groups of figures to each other is not the same as the average of the proportions worked out for each bone separately, unless the proportions in the series are all equal.
The Relative Length of the Head of the Talus

Although the length of the talus is liable to vary more than some of its other measurements, such as the breadth of the trocheae, I have used the length of the bone in calculating the relative length of the head in order to compare the results with those obtained by Poniatowski.

Measuring the length of the head in the same way as he did, i.e., the direct length, the following results were obtained:

**AUSTRALIAN TALUS**

- Average (Direct) Relative Length of Head = 62.3
- Maximum " " " " = 71.3
- Minimum " " " " = 55.3

**LEEDS TALUS**

- Average (Direct) Relative Length of Head = 51.3
- Maximum " " " " = 75.1
- Minimum " " " " = 50.0

The head of the Australian talus would appear to be longer in proportion to the size of the bone than are the Leeds bones.

When these figures are compared with those given by Poniatowski it is found that his result in the only group where he has measured more than 20 bones, the Tyrolean which is a European type of bone, agrees with the result for the Leeds talus, the average figures being 51.32 and 61.3.

His average for the Australian I cannot accept. It is 53.2 for 8 bones as against 62.3 for 73 bones from the Ramsay Smith Collection.

To test the reliability of the measurements made here, two groups of 3 Australian bones were selected at random and proved to have averages of 63.5 and 60.3. The whole series of Australian bones was then divided into three groups containing 31, 25, and 17 bones, and the average direct relative length of the head was estimated for each group:

- Group C, 17 bones, averaged 61.1.

To test the accuracy of the measurements and
calculations further, the Leeds bones were divided into two groups of 37 right and 39 left bones. In each case the average was found to be the same, 61.3.

It would seem that a series of about 30 bones is required to ensure reasonable accuracy.

The relative length of the head of the talus measured along the surface indicates, like the direct relative length and the proportions of the direct and surface lengths, a greater range of movement in the Australian than in the Leeds bones. The figures are as follows:

**AUSTRALIAN TALI**

- Average (Surface) Relative Length of Head = 92.0
- Maximum " " " " " = 113.0
- Minimum " " " " " = 73.1

**LEEDS TALI**

- Average (Surface) Relative Length of Head = 83.3
- Maximum " " " " " = 111.9
- Minimum " " " " " = 53.4

It was not found possible to measure the extent of the navicular facet proper because of the absence of a distinct line of demarcation between it and the facets due to the spring ligament and the tibialis posterior. Sufficient evidence is available, however, to point out clearly that the amount of movement possible at the talo-calcaneo-navicular joint must have been greater in the Australian than in the case of the individuals from whom the Leeds tali were derived.
General Description

Sewell (13a, p. 24j has described the lateral malleolar facet of the Ancient Egyptian talus in detail and his description, as in the case of other parts of the bone, applies in general to the Australian talus.

He notes that there is usually a notch in the anterior border of the facet, caused by the anterior talo-fibular ligament, and that the posterior angle of the facet is sharply defined by a groove for the posterior talo-fibular ligament. This groove passes forwards to the postero-inferior border of the facet and on to a notch below the middle of the articular surface, reaching the apex of the facet in 4 of the Egyptian bones as a result of lack of development of its apex.

In the Australian talus, the posterior notch is much more marked than the anterior one. Both of them were present in about 27% of cases; the posterior one, alone or with a faint indication of an anterior one, was present in 35% of cases, and the anterior one was present alone in only 6%. There was no indication of either anterior or posterior notching in 32% of cases. A line drawn between the two notches, when present, usually corresponds with the most pronounced part of the curve of the facet.

In practically all the Australian bones there is, in front of the facet, a ridge which runs parallel to the anterior border of the articular surface. This ridge runs from the region of the apex of the facet upwards and forwards towards the lateral border of the neck, in front of a triangular area which lies in the angle between the anterior margins of the trochlea and the malleolar facet and is pierced in its lower part by vascular foraminae. Here the ridge may end or become indistinct, but in a few bones it appears to become continuous with a roughness on the lateral margin of the neck and so with the ridge on the dorsum of the neck, as in no. 218/4 shown in fig. 61.

Fig. 61.
More frequently, however, the ridge on the dorsum of the neck becomes continuous with a roughening or ridge extending onto the roof of the sinus tarsi in its anterior part; as in the case of no. 130/2 L. shown in fig. 62, but the smoothing of the neck which is so frequently present tends to obscure the condition.

In some bones there is a smooth area between the anterior end of the ridge on the lateral surface and the ridge passing onto the roof of the sinus tarsi, in the position marked x in fig. 62. A possible explanation, and the only one which I can offer, is that it is due to pressure from the cruciate ligament when it is stretched over the region concerned during extreme inversion of the foot.

Behind the lateral malleolar facet, between it and the edge of the posterior calcaneal facet, there is a non-articular strip of varying width which Appleton (5, p.124) has described in relation to a number of Egyptian tali. He stated that the amount of variation in its width was large in a series of 353 Egyptian bones and found the range of variation to be from 7mm. to complete obliteration. Nine pairs of Australian tali, however, "showed uniformity in this feature". Since the width of this area depends largely upon factors which can be measured separately, and so give more information, I have not attempted to measure it in the Australian. An inspection of the Ramsay Smith series of bones shows that the amount of variation in width is probably quite as great as in the Ancient Egyptian. A relatively wide interval appeared to go, as a rule, along with the massive, well ossified type of bone and this is in
accord with Appleton's findings in regard to 17 young tali. He says that "as soon as ossification appears to be complete at this margin the two facets are always approximated".

The variation in shape of the lateral malleolar facet of the Australian tali is great, and is mostly due to alterations in the line of the margins by the notches for the talo-fibular ligaments. The curvature of the facet in a vertical direction is particularly diverse in form in any random group of bones. This is illustrated in fig. 83 but the number of intermediate forms makes it difficult to group them with any degree of accuracy.

As I have already mentioned, no trace of a talus secundarius as described by Pfitzner and, later, by Sewell was found among the Australian or Leeds bones.

![Tracings of the articular surfaces of the Australian talus, taken in a coronal plane passing through the apex of the lateral malleolar facet, i.e., in the plane of the transverse axis, to illustrate the variations in the curvature of the lateral malleolar facet.](image)
Measurements of the Lateral Process and Malleolar Facet

The amount of projection of the lateral process is a striking feature of the talus in certain races, and, although the articular surface may not always reach the tip of the process, it necessarily varies along with size of the process as a general rule.

Volkov (57, tabs. 33 & 39) has measured the width of the lateral malleolar facet in projection and concludes that it is more prominent in the lower than in the higher races and least of all in the European.

The average projection of the lateral process equals 21.3% of the total breadth of the bone in the Australian and 15.3% in the Leeds bones which I have measured (see pp. 223).

In the Neanderthal race, the development of the lateral process and the lateral malleolar facet have received considerable attention.

Virchow (58a, p. 145) remarked on the size of the lateral process of the Spy talus and measurement of a cast of it by myself, in the same way as was used when dealing with the Australian and Leeds tali, showed it to comprise 20% of the breadth of the bone. This is equivalent to the largest amount of projection found in the Leeds series, but less than the average for the Australian.

Fraipont (13, p. 3) says that the lateral malleolar facet of the Spy talus "présente un développement, un relèvement du sommet, plus accentué que dans la moyenne actuelle" and that the Mousterian average "est et restera sans doute bien supérieure aux moyennes actuelles et par conséquent plus voisins des moyennes des Anthropoides".

BuIe (8, p. 153) remarks on the development of the lateral malleolar facet of the talus from la Chapelle-aux-Saints, "développement qui rappelle celui qu'on observe chez les Anthropoides et, d'une manière générale, chez les mammifères grimpants".

Similarly, Jorjanović-Kracar (27, p. 297) describes the lateral process of the Khapina talus as being "stark seitwärts ausgewogen".

Humphry (240, p. 357) says of the Chimpanzee that the lateral malleolar facet "is larger than in Man and curved outwards at the lower end... indicating that a greater proportion of weight is transmitted in that direction along the outer border of the foot".
Poniatowski (159, tab. 3) compares the breadth of the trochlea with that of the talus. He then compares the size of the lateral malleolar facet with the breadth of the bone (table 3) and, basing his statement on the figures so obtained and on those of Volkov, says that the relative breadth of the lateral malleolar facet and its relative breadth in projection vary inversely with the breadth of the facies articularis superior. His statement is true but slightly misleading, since the breadth of the bone, with which the trochlea and the lateral facet are compared, varies with the amount of projection of the lateral process which is included in the breadth as measured by him.

He defines his measurement of the breadth of the lateral process (159, p.11) as the "Entfernung der unteren Spitze der Jelzenfläche auf dem proc. lat. tali von dem lateralen Rand der facies art. sup., in der transversalen Ebene gemessen". The phrase "transversalen Ebene" might give the impression that the breadth was taken in projection but his figures show that he must have measured the direct distance between the border of the trochlea and the apex of the facet in a vertical plane passing through the transverse axis. They are expressed as a percentage of the total breadth of the bone and are as follows:

<table>
<thead>
<tr>
<th>No. of bones, Race or Species, Average Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>4  Gorilla Gorilla                        53.5</td>
</tr>
<tr>
<td>12 Hylobates Synd.                        33.3</td>
</tr>
<tr>
<td>5  Simia Satyrus                          51.6</td>
</tr>
<tr>
<td>10  German                                 56.20</td>
</tr>
<tr>
<td>23  Tyrolean                               53.91</td>
</tr>
<tr>
<td>7  Tibetan                                 60.7</td>
</tr>
<tr>
<td>5  Patagonian                             81.2</td>
</tr>
<tr>
<td>6  Maori                                   53.3</td>
</tr>
<tr>
<td>3  Burmese                                 53.3</td>
</tr>
</tbody>
</table>

 seventeen (5, p.127) measured the depth of the lateral articular surface from the apex to the upper border of the facet, parallel to its anterior border.

After comparing a number of Ancient Egyptian talus with a few simian bones, and with Volkov's figures, he draws the conclusion that "the external malleolar facet is largest in Man". His article is difficult to follow but, after a
careful perusal of it, I cannot accept his statement.

He bases his conclusion on a comparison of the depth of the lateral malleolar facet with three standards, namely, the length of the bone, the width of the trochlea (as measured by himself and as given in Volkov's tables) and the length of the trochlea.

To compare the depth of the facet with the length of the bone he takes the latter measurement as unity and expresses the depth of the facet as a proportion of it. His figures are as follows:

<table>
<thead>
<tr>
<th>Number of bones, race or species</th>
<th>Depth of Lateral Facet (Length of bone = unity)</th>
</tr>
</thead>
<tbody>
<tr>
<td>363</td>
<td>Ancient Egyptian 0.439</td>
</tr>
<tr>
<td>3</td>
<td>Gorilla 0.43</td>
</tr>
<tr>
<td>7</td>
<td>Chimpanzee 0.42</td>
</tr>
<tr>
<td>12</td>
<td>Orang 0.40</td>
</tr>
</tbody>
</table>

This would indicate that the facet is "largest in Man", but Appleton himself (ibid. p.123) states that this standard of comparison is "found open to suspicion" on account of variations in the length of the neck of the bone. He also mentions the "abnormally great astragalar length" in the Orang and this must render the figure for that animal too small and of little use for purposes of comparison. Except in the case of the Egyptian series, the number of bones measured is insufficient to yield reliable results.

In regard to the trochlear width, Appleton found that its correlation with other standards, such as the length of the bone, the length of the trochlea and the axial height, "is not close". This is, no doubt, due to the fact that he measured the breadth of the trochlea at its posterior end where there is a considerable amount of variation.

To compare the depth of the lateral malleolar facet with the trochlear width he took the width of the trochlea relative to the length of the bone as unity and expressed the depth of the facet relative to the length of the bone as a proportion of it. The figures so obtained are as follows:

- Man (Ancient Egyptian) 0.31,
- Orang 0.30,
- Gibbon 0.35(?) *
- Chimpanzee 1.0,
- Gorilla 1.07,
- One Cynocephalus 0.77.

*The query is Appleton's
The figure for Man is apparently based on 15 calculations of the value of the relative breadth of the trochlea, and the number of bones used in obtaining the figures for the Apes is not stated.

In any case, since the depth of the facet is, in effect, expressed as a proportion of the width of the trochlea, a large index represents a large facet. Thus, the lateral facet would appear to be distinctly smaller in Man than in the Gibbon, Chimpanzee or Gorilla.

In addition, Appleton appears to have used average ratios in making his calculations instead of making each calculation separately. To take one example, the average relative trochlear width given by Appleton for the Gorilla is 0.40; the average relative height of the lateral facet is 0.13, and 13/40 = 1.07 which is the figure given for the height of the lateral facet relative to the width of the trochlea for that animal.

Again, if the figures given by Appleton (ibid. p.123) for the depth of the lateral malleolar facet relative to the length of the trochlea are examined, it will be found that they do not afford the slightest proof of the statement that the lateral malleolar facet is "largest in Man".

They are:-

<table>
<thead>
<tr>
<th>Number of Bones, Race or Species, (Trochlear Length = 1)</th>
<th>Depth of Lateral Facet</th>
</tr>
</thead>
<tbody>
<tr>
<td>383 Ancient Egyptian</td>
<td>0.70</td>
</tr>
<tr>
<td>3 Gorilla</td>
<td>0.63</td>
</tr>
<tr>
<td>7 Chimpanzee</td>
<td>0.73</td>
</tr>
<tr>
<td>14 Orang</td>
<td>0.72</td>
</tr>
<tr>
<td>3 Gibbon</td>
<td>0.6</td>
</tr>
</tbody>
</table>

The figure for Man is lower than those for the Orang and Chimpanzees, though the other two species have considerably smaller indices. In addition, 11 Egyptian bones with facies calcanea accessorii had an average index of 0.37, and 17 young bones had an index of 0.32.

The number of simian bones used was small and, further, the number, 363, given for the random series of Egyptian bones, is deceptive. The figure 0.70 is "calculated by Table II". Table II, the relative length of the trochlea, shows that the following numbers of bones were used: Series R & S...24; With fac. calo. access...13; Young...17.

*see page 6.
I have measured the depth of the lateral malleolar facet of the Australian and Leeds talus in the manner followed by Poniatowski, namely, from the apex of the facet directly to its upper border in a coronal plane.

Appleton's method was rejected owing to the difficulty of drawing a straight line parallel to the anterior border of the facet. The border in question is seldom straight and is frequently much distorted by the anterior talo-ticular ligament. Poniatowski's method of comparing the depth of the facet with the breadth of the bone was discarded because of the extent to which the breadth varies with the size of the lateral process.

The results of these measurements are shown below and indicate that the lateral malleolar facet is definitely larger, in proportion to the size of the bone, in the Australian than in the Leeds talus.

### Depth of Lateral Malleolar Facet

<table>
<thead>
<tr>
<th></th>
<th>Absolute Measurements</th>
<th>Relative to Length of Talus</th>
<th>Relative to Length of Trochlea</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average</td>
<td>Maximum</td>
<td>Minimum</td>
</tr>
<tr>
<td></td>
<td>22.3 mm.</td>
<td>23 mm.</td>
<td>13 mm.</td>
</tr>
<tr>
<td></td>
<td>22.3 mm.</td>
<td>27 mm.</td>
<td>22 mm.</td>
</tr>
<tr>
<td>No. of Bones</td>
<td>39 (27 pairs)</td>
<td>32 (unpaired)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

These figures are not comparable to any given by Appleton.

The depth of the lateral malleolar facet of the Spy cast in the same way is 31 mm, which is equivalent to 93% of the breadth of the trochlea, 31.3% of the length of the trochlea and 36.4% of the length of the bone.

It would appear that the depth of the lateral facet keeps pace fairly well with the amount of projection of the lateral process and a closer examination of the Australian series supports this view.
Using the depth of the lateral malleolar facet relative to the length of the bone as a standard for comparison, it was found that the Australian talus with deep lateral facets had, as a rule, prominent lateral processes.

The average relative depth of the facet is 13.3 and the average projection of the process is 21.3% of the breadth of the bone. Bones with a relative depth of 13.3 or less have an average projection 20.3%, and those with a relative depth of 15.3 or more have an average projection of 22.7%.

![Graph showing the relationship between the depth of the lateral malleolar facet and the projection of the process.](image)

I have grouped the Australian talus according to the depth of the lateral malleolar facet, and have worked out the average amount of projection of the lateral process beyond the margin of the trochlea for each group. The results are shown in the form of a graph in Fig. 61 and, though the curve is not very even, its general trend is obvious. A deep facet usually goes along with a prominent lateral process.
The Posterior Calcanean Facet

The posterior calcanean facet has been dealt with by few authors and records of measurements are scanty in the available literature. Also, the methods of measurement adopted by various authors differ.

Sorjanović-Kramberger (20, p.241) measured the "Längs der hinteren Gelenkfläche für den Calcaneus, vorn". As in the case of his previous definitions, this is somewhat indefinite.

Fraipont (19) and Volkov (57) each measured the greatest length of the facet, while Poniatowski (150, p.12) used the distance between the two ends of the "Mittlere-längskurve", on the edge of the articular surface.

The breadth of the facet has been measured in two ways. Volkov, Sorjanović-Kramberger and Fraipont measured it perpendicular to the mid-point of the long axis of the articular surface, but Poniatowski pointed out that the greatest breadth occurred about the middle of the facet in Man and that it is situated towards the medial end in the Apes. He accordingly measured the greatest breadth of the facet, perpendicular to the long axis, wherever it happened to be in the bone being measured.

The definitions of the length are, for practical purposes, comparable and I have measured the distance between the edges of the articular surface in the long axis of the facet when dealing with the Australian and Leels bones.

The two methods of measuring the breadth are, however, not comparable with each other and I have measured the breadth of the facet in both ways, taking the breadth perpendicular to the middle of the long axis and, also, the greatest breadth perpendicular to the long axis.

Of the two methods, I am inclined to regard the one which uses the mid-point of the long axis as being the more reliable one. The greatest breadth, when it does not occur in the middle of the facet, is always at the medial end and is aided to by a prolongation onto the under surface of the posterior process which varies considerably in size.
I have expressed the measurements of the length and breadth of the posterior calcanean facet as a percentage of the length of the bone, with the following results:

<table>
<thead>
<tr>
<th>Relative Length of the Posterior Calcanean Facet</th>
<th>AUSTRALIAN</th>
<th>LEEDS D.R.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>60.7</td>
<td>53.7</td>
</tr>
<tr>
<td>Maximum</td>
<td>63</td>
<td>64</td>
</tr>
<tr>
<td>Minimum</td>
<td>53</td>
<td>34</td>
</tr>
<tr>
<td>No. of Bones</td>
<td>61 (11 pairs)</td>
<td>30 (unpaired)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Relative Breadth of the Posterior Calcanean Facet</th>
<th>AUSTRALIAN</th>
<th>LEEDS D.R.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Greatest Breath</td>
<td>AUSTRALIAN</td>
<td>LEEDS D.R.</td>
</tr>
<tr>
<td>Average</td>
<td>42.3</td>
<td>41.9</td>
</tr>
<tr>
<td>Maximum</td>
<td>51</td>
<td>49</td>
</tr>
<tr>
<td>Minimum</td>
<td>35</td>
<td>35</td>
</tr>
<tr>
<td>No. of Bones</td>
<td>101 (23 pairs)</td>
<td>35 (unpaired)</td>
</tr>
<tr>
<td>B. Breadth in Middle</td>
<td>AUSTRALIAN</td>
<td>LEEDS D.R.</td>
</tr>
<tr>
<td>Average</td>
<td>41.4</td>
<td>39.8</td>
</tr>
<tr>
<td>Maximum</td>
<td>47</td>
<td>45</td>
</tr>
<tr>
<td>Minimum</td>
<td>35</td>
<td>32</td>
</tr>
<tr>
<td>No. of Bones</td>
<td>93 (25 pairs)</td>
<td>38 (unpaired)</td>
</tr>
</tbody>
</table>

Assuming that the length of the bone is a reliable standard of comparison, the above figures indicate that the posterior calcanean facet of the Australian talus is both longer and broader than is the case in the Leeds series of bones.

If, however, the length of the bones varies, apart from its size, in the two races, the probability is that it is shorter in the Australian, so that the extra length of the Leeds bones relative to that of the Australian talus might account for an apparent reduction in the size of the facet in the Leeds series.

Appleton (3, p.127) suggested the length or breadth of the trochlea as reliable standards with which to compare other parts of the bone.

The relative length of the trochlea is 61.7 for the Australian as compared with 63 for the Leeds talus. This would indicate, if the length of the trochlea is a sound standard, that the length of the talus is greater in the Australian, and that the relative length and breadth of the
Australian posterior calcanean facet should be still larger in comparison with the figures for the Leeds bones than is indicated by the figures shown above.

My own view is that the trochlea is short in the Australian and is not a good standard upon which to base comparisons.

The breadth of the trochlea may prove to be a better standard with which to compare other measurements, provided it is taken in the plane of the transverse axis and not posteriorly as was done by Appleton. Compared with the length of the bone, it appears to be larger than the Leeds trochlear breadth owing to the shortness of the Australian compared with the Leeds talus. Compared with the breadth of the bone it appears to be smaller in the Australian owing, mainly, to the size of the lateral process in that race. Compared with the length of the trochlea, it appears to be larger in the Australian because of the shortness of the trochlea.

I have, accordingly, worked out the length of the calcanean facet of the Australian and Leeds bones relative to the breadth of the trochlea, with the following results:

<table>
<thead>
<tr>
<th>Length of Post. Calcanean Facet rel. to Breadth of Trochlea</th>
<th>AUSTRALIAN</th>
<th>LEEDS D.R.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>111.3</td>
<td>110.3</td>
</tr>
<tr>
<td>Maximum</td>
<td>135.</td>
<td>120</td>
</tr>
<tr>
<td>Minimum</td>
<td>95</td>
<td>93</td>
</tr>
<tr>
<td>No. of Bones</td>
<td>59 (14 pairs)</td>
<td>29 (unpaired)</td>
</tr>
</tbody>
</table>

The differences between the indices of the two races is equivalent to about half of the difference obtained when the index is based on the length of the bone.

Judged by this standard, it would seem that the facet is still longer in the Australian than in the Leeds series of bones.

The Shape of the Posterior Calcanean Facet

The shape of the posterior calcanean facet is usually described as being oval or quadrilateral, and Poniatowski states that the greatest breadth occurs in the middle of the facet in Man and towards the medial end in the Apes.

In the case of the Australian I have found the greatest breadth to be towards the medial end of the facet in 38 out
of 35 bones, 49%. In the Leeds series the breadth was found to be greatest at the medial end in 24 out of 40 bones, 60%. This difference between the two races can be seen in the figures for the relative breadth of the posterior calcaneal facet, the difference between the breadth as measured in the middle of the facet and the greatest breadth being equivalent to 9.3% of the length of the talus in the Australian and 2.3% of the length of the talus in the Leeds series.

This dissimilarity between the Leeds and Australian bones is also apparent in the case of the length-breath index of the facet. The difference between the index based on the greatest breadth and that based on the breadth measured across the long axis is nearly four times greater in the Leeds than in the Australian tali.

The reason why the greatest breadth of the posterior calcaneal facet is so frequently towards the medial end of the facet in the Leeds bones is that the articular surface is more frequently prolonged backwards in the medial half of the facet. The prolongation backwards is onto the under surface of the posterior process and would seem to be related to the degree of development of the lateral part of the process, i.e., the part which is associated with the os trigonum.

![Fig. 35](image)

**Fig. 35.**

Fig. 35 illustrates the condition referred to, as it occurs in two of the Leeds tali.

The projection forwards, which also supplements the greatest breadth of the facet in these bones, is commoner in the Australian than in the Leeds bones.
Poniatski concludes that primitive races have a narrower posterior calcanean facet than the higher races. The figures for the length-breath index upon which he bases this statement are his own and those of Volkov. His own are calculated from the greatest breadth of the facet, while those given by Volkov are based on measurements of the breadth across the middle of the long axis of the facet.

The two tables shown below indicate the results obtained by Poniatski and by Volkov:

### Length-breath index of post. calcane. facet (Poniatski)

<table>
<thead>
<tr>
<th>Race or Species</th>
<th>No. of Bones</th>
<th>Average L-B. Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simia Satyrus</td>
<td>5</td>
<td>83,2</td>
</tr>
<tr>
<td>Hylobates Syimp.</td>
<td>11</td>
<td>84,9</td>
</tr>
<tr>
<td>Gorilla Gorilla</td>
<td>7</td>
<td>77,4</td>
</tr>
<tr>
<td>Australian</td>
<td>8</td>
<td>62,5</td>
</tr>
<tr>
<td>Patagónian</td>
<td>5</td>
<td>84,4</td>
</tr>
<tr>
<td>Tibetan</td>
<td>3</td>
<td>64,7</td>
</tr>
<tr>
<td>Maori</td>
<td>3</td>
<td>66,3</td>
</tr>
<tr>
<td>Burmese</td>
<td>3</td>
<td>67,1</td>
</tr>
<tr>
<td>Tyrolean</td>
<td>24</td>
<td>69,0</td>
</tr>
<tr>
<td>German</td>
<td>19</td>
<td>70,11</td>
</tr>
</tbody>
</table>

### Length-breath index of post. calcane. facet (from Volkov)

<table>
<thead>
<tr>
<th>Race</th>
<th>Sex</th>
<th>No. of Bones</th>
<th>Average L-B. Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Europ.(newborn) M</td>
<td>4</td>
<td>81,1</td>
<td></td>
</tr>
<tr>
<td>Negro</td>
<td>M</td>
<td>3</td>
<td>82,9</td>
</tr>
<tr>
<td>Malayesian</td>
<td>M</td>
<td>7</td>
<td>83,2</td>
</tr>
<tr>
<td>Japanese</td>
<td>M</td>
<td>13</td>
<td>61,5</td>
</tr>
<tr>
<td>&quot;</td>
<td>F</td>
<td>7</td>
<td>83,2</td>
</tr>
<tr>
<td>&quot;</td>
<td>M &amp; F</td>
<td>25</td>
<td>85,5</td>
</tr>
<tr>
<td>Negrito</td>
<td>F</td>
<td>3</td>
<td>63,4</td>
</tr>
<tr>
<td>&quot;</td>
<td>M</td>
<td>10</td>
<td>83,3</td>
</tr>
<tr>
<td>&quot;</td>
<td>M &amp; F</td>
<td>13</td>
<td>83,1</td>
</tr>
<tr>
<td>European</td>
<td>F</td>
<td>23</td>
<td>83,4</td>
</tr>
<tr>
<td>&quot;</td>
<td>M</td>
<td>30</td>
<td>70,0</td>
</tr>
<tr>
<td>&quot;</td>
<td>M &amp; F</td>
<td>53</td>
<td>69,3</td>
</tr>
</tbody>
</table>

With the exception of the European bones, and perhaps the Japanese, the number of indices available in each group is too small for accurate conclusions to be possible.
The length-breadth index of the posterior calcanean facet, calculated (A) from the greatest breadth of the facet and (B) from its breadth across the middle of the long axis of the facet, is shown below for the Leeds and Australian tali.

**Length-Breadth Index of the Posterior Calcanean Facet**

<table>
<thead>
<tr>
<th></th>
<th>Greatest Breadth</th>
<th></th>
<th>Breadth in middle</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AUSTRALIAN</td>
<td></td>
<td>LEEDS D.R.</td>
</tr>
<tr>
<td>A.</td>
<td>Average</td>
<td>39.3</td>
<td>72.1</td>
</tr>
<tr>
<td></td>
<td>Maximum</td>
<td>35.</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>Minimum</td>
<td>31</td>
<td>59</td>
</tr>
<tr>
<td></td>
<td>No. of Bones</td>
<td>63 (11 pairs)</td>
<td>31 (unpaired)</td>
</tr>
<tr>
<td>B.</td>
<td>Average</td>
<td>63.3</td>
<td>67.9</td>
</tr>
<tr>
<td></td>
<td>Maximum</td>
<td>32</td>
<td>76</td>
</tr>
<tr>
<td></td>
<td>Minimum</td>
<td>30</td>
<td>59</td>
</tr>
<tr>
<td></td>
<td>No. of Bones</td>
<td>63 (12 pairs)</td>
<td>30 (unpaired)</td>
</tr>
</tbody>
</table>

The range of variation is sufficiently large to render the results of doubtful value and, though the two series of bones examined by Volkov and Poniatowski suggest that the posterior calcanean facet is broad in the European and narrower in what are usually regarded as the lower races, this is not supported by the measurements carried out here on bones from races at the two ends of the scale.

The difference between the Leeds and Australian indices when the greatest breadth of the facet is used in the calculation can be accounted for to a great extent by the large size of the lateral part of the posterior process in the Leeds bones. If the extension of the articular surface onto the under aspect of this part of the bone is excluded from the measurement of the breadth of the facet, then the Australian and Leeds proportions are similar, though the facet as a whole is larger in the Australian.

**The Depth of Curvature of the Posterior Calcanean Facet**

The frequency of the occurrence of slight damage to the edges of the posterior calcanean facet proved to be one of the main difficulties encountered when measuring it. This was particularly so in the case of measurements of the depth of the curvature, so that only 23 Leeds bones were available for comparison with the 34 Australian ones which were sufficiently intact to yield both the length and the depth of the facet.
The depth was measured by means of the modified "Columbus" gauge already employed in the measurement of the depth of the groove on the trochlea and the depth of the hollow of the medial malleolar facet. The horizontal bar was placed across the size of the two ends of the facet, along the line of the long axis, and the depth was measured perpendicularly to the farthest point on the articular surface.

The average depth proved to be 6.3 mm. for the Leeds and 5.3 mm. for the Australian specimens.

The results of the measurements are shown below, expressed as a percentage of the length of the facet:

Length-Depth of the Posterior Calcanean Facet

<table>
<thead>
<tr>
<th></th>
<th>Australian</th>
<th>Leeds D.R.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>13.3</td>
<td>20.0</td>
</tr>
<tr>
<td>Maximum</td>
<td>23</td>
<td>23</td>
</tr>
<tr>
<td>Minimum</td>
<td>14</td>
<td>13</td>
</tr>
<tr>
<td>No. of Bones</td>
<td>54 (13 pairs)</td>
<td>23 (unpaired)</td>
</tr>
</tbody>
</table>

This is again insufficient evidence that there is any difference between the Australian and Leeds bones.

Poniatowski concluded that a deep curvature of the posterior calcanean facet represents primitive conditions, as opposed to the stability which characterises the higher races. The figures upon which he bases this conclusion (450, table 12) are shown below along with Reicher's figures for the length-height index of the corresponding facet on the calcaneus (16, p.122):

<table>
<thead>
<tr>
<th>Race or Species</th>
<th>No. of Specimens</th>
<th>L-D. Index</th>
<th>No. of L-H. Index of Facet on Calcaneus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gorilla Gorilla</td>
<td>8</td>
<td>13.3</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>24.3</td>
</tr>
<tr>
<td>Simia Satyrus</td>
<td>3</td>
<td>20</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>23.5</td>
</tr>
<tr>
<td>Hylobates Synd.</td>
<td>-</td>
<td>----</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>32.2</td>
</tr>
<tr>
<td>Australian</td>
<td>8</td>
<td>13.2</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>13.0</td>
</tr>
<tr>
<td>German</td>
<td>18</td>
<td>13.31</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>17.2</td>
</tr>
<tr>
<td>Tyrolean</td>
<td>23</td>
<td>13.57</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>13.4</td>
</tr>
<tr>
<td>Swiss</td>
<td>-</td>
<td>----</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>13.8</td>
</tr>
<tr>
<td>Senoi'</td>
<td>2</td>
<td>13.5</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>----</td>
</tr>
<tr>
<td>Burmese</td>
<td>3</td>
<td>23.9</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>20.1</td>
</tr>
<tr>
<td>Maori</td>
<td>2</td>
<td>21.5</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>----</td>
</tr>
<tr>
<td>Tibetan</td>
<td>7</td>
<td>22.3</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>22.1</td>
</tr>
<tr>
<td>Patagonian</td>
<td>5</td>
<td>22.4</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>22.6</td>
</tr>
</tbody>
</table>
Reicher's figures agree well with those given by Poniatowski but they are very probably derived from the same series of bones. Consequently, while the results verify the accuracy of the measurements in each case, the outstanding defect remains the same. The numbers of bones in each group are far too small in view of the wide range of variation within one race, and I do not consider that Poniatowski is justified in drawing the conclusion mentioned above. It may be added here that Humphry (24, p.257) noted, from the dissection of one specimen, that the posterior calcanean facet was "less flat in the Chimpanzee than in Man, and formed for movement in the former rather than for the endurance of weight". Adachi (1, p.313) found that the curve of the posterior calcanean facet was deeper in the Japanese tali which he examined than in the case of the European talus.

The posterior calcanean facet of the Australian talus would appear to be as shallow as, or shallower than, that of more modern types of bone, in spite of the wide range of movement which appears to have been possible at the joints of the foot in the Australian.

A wide range of movement between the talus and the calcaneus appears to have been provided for by an increase in the size of the articular surface rather than by a deep curvature of the posterior calcanean facet. It is also possible that, during forced inversion of the foot when the exaggerated sartorial position is adopted, the calcaneus is thrust bodily over on the under surface of the talus so as to increase the length of the posterior calcanean facet on the talus. The breadth is also increased by changes in the region of the anterior border (to be described in the following section) so that the length-breath index is not appreciably altered by the increase in length.

Changes in the region of the Anterior Border of the Facet

An inspection of the posterior calcanean facet of the Australian and Leeds bones showed a distinct difference in the frequency of the occurrence of two conditions in the series. These conditions are a beveling of the anterior border of the facet at its lateral end and a spreading of the articular surface at the medial end of that border.

The beveling of the anterior edge of the facet is
variable in extent, but it usually occupies the border in its lateral half and extends almost as far round as the level of the apex of the lateral process. In its most marked form it becomes a prolongation of the articular surface onto the anterior aspect of the lateral process.

Out of 109 Australian and 30 Leeds bones it was present to a greater or less degree in 21% of the former and in 13% of the latter.

I have arranged the bones in groups:- where the condition was absent, doubtful cases, where it was slight but definite, marked cases, and very marked cases. The frequency of occurrence of the different degrees of the condition is shown below:-

<table>
<thead>
<tr>
<th>Condition</th>
<th>Australian</th>
<th>Leeds D.R.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absent</td>
<td>86%</td>
<td>32%</td>
</tr>
<tr>
<td>Doubtful</td>
<td>10%</td>
<td>23%</td>
</tr>
<tr>
<td>Present Marked</td>
<td>13%</td>
<td>30%</td>
</tr>
<tr>
<td>Very Marked</td>
<td>6%</td>
<td>13%</td>
</tr>
<tr>
<td>None</td>
<td>13%</td>
<td>9%</td>
</tr>
</tbody>
</table>

It will be seen that this bevelling or prolongation of the lateral part of the articular surface is much more pronounced in the case of the Leeds bones than in the Australian specimens.

Fig. 83 shows a photograph of one of the Leeds tali placed alongside the calcaneus from the same foot.

The area in question, marked 1, comes into contact with a corresponding area of smoothing, similarly marked, on the calcaneus when the bones are in a position such as they
must occupy during extreme eversion of the foot.

Fick (13, p.121) mentions that he found the cartilage in this region "auf die Vorderseite des Knochens Übergreifend" in fresh specimens, and that there is often "ein besonderer Überknorpelter Wulst" on the calcaneus. He also remarks that the part of the talus referred to does not articulate with the calcaneus, but with the anterior and lateral talo-calcanean ligaments. The area, marked 1, shown on the calcaneus illustrated in fig. 33 was separated by a slight interval from the posterior facet for the talus.

I have no hesitation in saying that the condition described above and illustrated in fig. 36 is due to the frequent adoption of a position of the calcaneus such as occurs during strong eversion of the foot. Many of the bones in the Leeds dissecting rooms are, naturally, from tramps and the condition may well be the result of the habit of "hunkering down", squatting on the heels with the soles of the feet flat on the ground. This position involves a dorsiflexion of the ankle joint along with forced eversion of the foot.

Sewell (13a, p.431) has described this bevelling of the edge of the posterior calcanean facet as occurring in his series of Ancient Egyptian talii and gives its most pronounced form, as illustrated in fig. 33, the name facies externa accessoria corporis tali. He found it in 102 cases or 10.15% of the series.

He found also that the auricular facet was prolonged forwards onto the neck in almost all the bones where the accessory facet was present, three specimens only being unaccompanied by the forward prolongation, while "in 20% of cases a distinct internal facet was present on the upper surface of the neck". Following this, he "found indications of this (accessory) facet to be present in the astragali of the anthropoid apes..." according to the following table:-

<table>
<thead>
<tr>
<th>Species</th>
<th>No. of bones, facet present, facet doubtful</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gorilla</td>
<td>7</td>
</tr>
<tr>
<td>Chimpanzee</td>
<td>5</td>
</tr>
<tr>
<td>Orang utan</td>
<td>15</td>
</tr>
<tr>
<td>Gibbon</td>
<td>3</td>
</tr>
</tbody>
</table>

He points out that the forward prolongation of the auricular facet is frequent in these Apes and then makes
the following statement:— "From the consideration of the above facts, I have come to the conclusion that both the presence of this facet and the forward prolongation of the facies malleolaris interna are to be attributed to the influence of the same factors, namely, the constant dorsiflexion and inversion of the ankle joint in the sartorial position. In this position the tibia presses on the neck of the astragalus, and this pressure is transmitted on to the bone below; the astragalus thus becomes forced down on to the calcaneum and this gives rise to the facies externa accessorio corporis tali".

The talus and calcaneus only require to be placed in position for it to be obvious that, when the foot is inverted, pressure from the tibia will force the head of the talus down onto the anterior facet on the calcaneus, but that it is impossible for the accessory facet to approach the corresponding area of smoothing on the calcaneus. The inevitable result of any attempt to bring them together is to produce a movement of the calcaneus which corresponds to eversion of the foot.

Moreover, this accessory facet on the talus is relatively infrequent in the Australian, where inversion would appear to be the rule when squatting and where the medial malleolar facet usually passes far forwards with an accompanying "internal facet" on the dorsum of the neck; while it is more common and more marked in the case of the Leeds tali which are drawn from a portion of the populace in whom squatting with the foot in an everted position is known to occur.

The correct interpretation of Jewell's findings would seem to be that the prolongation of the medial malleolar facet and the so-called medial facet on the dorsum of the neck are the result of habitual strong dorsiflexion of the ankle, whether it be accompanied by inversion or by eversion of the foot; that the accessory facet or bevelling of the margin of the posterior calcaneal facet is the result of eversion of the foot, and that, in the case of the Apes, the shape of the bones and the normal position of inversion result in the production of the accessory facet when any attempt towards eversion is frequently made, that is to say, even when the weight of the body is put on the (outer border of the) foot when the animal is on the ground.
The second condition to be described, and already referred to as a spreading of the articular surface, occurs at the medial side of the anterior border of the posterior palatine facet. It consists of a prolongation forwards and spreading out of the articular surface, accompanied by an alteration in the shape or surface of the facet in that region. In one case, no. 301/1a of the Australian series, the posterior palatine facet has been prolonged far enough forwards to lose with the middle palatine facet across the sinus inlet. Scull (13a, p. 151) mentions that the two facets were in one case and fused in one other case in his ancient Egyptian series.

![Diagram](image)

**Fig. 37**

The area concerned is marked in figs. 33 and 37. It tends to be convex in a direction at right angles to the long axis of the facet, and the curvature in the direction of the long axis is more markedly concave than normally, so that the concavity of the facet in its anterior half becomes more accentuated as the medial side is approached. The impression produced is as though a thumb had been placed firmly on the medial half of the facet of a soft bone and then pressed forwards, upwards and slightly medially.

In cases where this spreading affects the bone in to the medial side of the facet the articular surface may pass for a short distance onto the under aspect of the medial tubercle. It usually increases the breadth of the root on to, i.e., to the lateral side of, the level of the middle of the long axis, and will thus affect the measurement of
the breadth of the facet and the value of the length—

breadth index.

In arranging the Australian and Leeds bones into
groups, cases where the prolongation occurs was absent,
but the curvature was such as to suggest that the same
factor had been at work, have been included among the
iontal specimens.

Out of 133 Australian and 92 Leeds bones the condition
was absent or iontal in 81% of the former and in 53% of
the latter, and present to a greater or less extent in 33%
and 45% respectively. The groupings are shown below:

"Spreading" of the anterior part of the Post. Calcan. Facet

| No. of Bones | Absent | Iontal | Present | Marked | Very Marked
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>133 AUSTRALIAN</td>
<td>20%</td>
<td>14%</td>
<td>32%</td>
<td>33%</td>
<td>5%</td>
</tr>
<tr>
<td>92 Leeds D.R.</td>
<td>39%</td>
<td>29%</td>
<td>19%</td>
<td>13%</td>
<td>6%</td>
</tr>
</tbody>
</table>

When a bone showing this spreading is placed in
position on the calcaneus from the same foot it is obvious
that the area concerned is in contact with the most medial
part of the talaric facet on the calcaneus, and that the
condition described will be produced if the calcaneus is
forcibly rotated so as to thrust the medial part of its
facet up against the facet on the talus. This would occur
during strong inversion of the foot such as must take place
in the exaggerated sartorial position.

To sum up, a condition of the posterior calcaneal
facet which is favoured by habitual inversion of the foot
prevails in the Australian series of bones, whilst a
condition favoured by habitual eversion predominates in the
Leeds series; each of these two conditions is precisely
the result of squatting, the first being produced by the
sartorial position, the second being produced by "hunkering
down".

The presence of both conditions in the one bone may be
explained by the occupation of the individual, mining, for
example.
The Angle between the Long Axis of the Posterior Calcanean Facet and the Long Axis of the Trochlea

The angle at which the posterior calcanean facet is inclined to the long axis of the trochlea has been dealt with by Snow, Trajont, Martin and Foniatowski.

Snow (13a, p.180) stated that the long axis of the facet in the Egyptian was directed forwards and outwards, making an angle of approximately 45° with the antero-posterior axis of the bone. He does not define the axis of the bone, but it is usually taken as coincident with the axis of the trochlea.

Martin (37b, p.313) gave the angle between the axes as 55° for the European and 35° for the Sanoi talus.

Trajont (13, p.241), when dealing with the Spy talus, said that the posterior calcanean facet was "la plus transversal chez l'Européen actuel, déjà plus antéro-postérieure chez l'homme de Spy, elle devient encore plus d'avantage chez la gorille; ce caractère s'accentue chez troglodytes et est maximum chez simia satyrus où la facette postéro-externe est pour ainsi dire antéro-postérieure".

The Spy cast yields an angle of about 13° according to my own measurements, but the articular margin appears to have been slightly damaged.

Foniatowski (15a, p.14) measured the angle between the "Mittlerelängskurve" of the facet and the sagittal plane (which passes through the long axis of the trochlea). His results are shown below:

<table>
<thead>
<tr>
<th>Race or Species</th>
<th>No. of Bones</th>
<th>Angle + or -</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hyloastes Syli.</td>
<td>11</td>
<td>21.15° 0.39°</td>
</tr>
<tr>
<td>Simia Satyrus</td>
<td>5</td>
<td>23.3° 2.3°</td>
</tr>
<tr>
<td>Gorilla Gorilla</td>
<td>5</td>
<td>40.2° 2.7°</td>
</tr>
<tr>
<td>Australian</td>
<td>5</td>
<td>37.7° 1.0°</td>
</tr>
<tr>
<td>Sanoi</td>
<td>2</td>
<td>33.3° ---</td>
</tr>
<tr>
<td>German</td>
<td>21</td>
<td>33.32° 0.35°</td>
</tr>
<tr>
<td>Tyrolean</td>
<td>24</td>
<td>41.12° 0.17°</td>
</tr>
<tr>
<td>Patagonian</td>
<td>5</td>
<td>11.1° 0.3°</td>
</tr>
<tr>
<td>Burmese</td>
<td>3</td>
<td>15.3° 0.3°</td>
</tr>
<tr>
<td>Maori</td>
<td>2</td>
<td>17° ---</td>
</tr>
<tr>
<td>Tibetan</td>
<td>7</td>
<td>43.5° 0.4°</td>
</tr>
</tbody>
</table>

Fick (13a, p.125) gives the angle between the "vordere Fläsc" of the facet and the medial border of the trochlea as being 60° in the European.
In the case of the Australian and Leeds tali, I have measured the angle between the long axis of the posterior calcaneal facet and that of the troohlea. The bone to be measured was placed on the under surface of a glass plate and fixed there with the long axis of the facet parallel to a line rule on the glass; the plate was then reversed and placed over a line rule on a plane surface, and adjusted, with the aid of a thread stretched over the troohlea, till this second line was parallel to the long axis of the troohlea. The angle between the two lines was then measured to the nearest 1° by means of a large protractor. The results are shown in the table below:-

<table>
<thead>
<tr>
<th>Angle between Long Axes of the</th>
<th>Troohlea and Post. Cal. Facet</th>
<th>AUSTRALIAN</th>
<th>LEEDS C.R.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>45.7°</td>
<td>45.5°</td>
<td></td>
</tr>
<tr>
<td>Maximum</td>
<td>57°</td>
<td>53°</td>
<td></td>
</tr>
<tr>
<td>Minimum</td>
<td>31°</td>
<td>35°</td>
<td></td>
</tr>
<tr>
<td>No. of Bones</td>
<td>97(27 pairs)</td>
<td>33(unpaired)</td>
<td></td>
</tr>
</tbody>
</table>

The wide range of variation in both the Australian and the Leeds series is not very satisfactory, but, when the Australian bones were grouped at random, the average angles obtained were 45° for 29 bones, 45.3° for 34 bones and 45.2° for 31 unpaired bones; so that the average results from this method of measurement may be regarded as fairly accurate.

The figures obtained from the Australian and Leeds bones do not support the observations of Fraipont and Poniatowski; they suggest rather that there is no difference (as regards the angle in question) between the Australian and the modern civilised type of talus represented by the specimens from the Leeds Dissecting Rooms.

It may be, however, that the angle is increased in the Australian tali by the frequency of the forward prolongation which occurs at the medial side of the facet. Also, an inspection of the Australian and Leeds tali shows that the articular area on the under surface of the lateral part of the posterior projects further back and is larger in the case of the Leeds bones. Allowance for these two factors would render the results for the Australian distinctly smaller than those for the Leeds series.
It seemed probable, since the talo-calcaneal joint is
concerned in the movements of inversion and eversion of
the foot, that the angle at which the posterior calcaneal
facet is set to the axis of the trochlea would vary
inversely with the angle of the neck measured in a
horizontal plane. These two angles were accordingly
compared in each of the Australian tali, but the results
were negative.

13 bones with an inclination of the posterior calcaneal
facet of 45° or less had an average horizontal angle of the
neck of 23,7°, while 32 bones with an inclination of the
facet of 45° or more had an average angle of the neck of
23,7°. Any attempt at subdivision of the groups simply
produced irregular variations.

**The Talo inferior Accessoria Corporis Tali**

Descriptions of this accessory facet are given by
Pfitzner (12, p.215) and Sewell (13a, p.123). It is
situated on the under surface of the medial tubercle and on
the ridge which runs forwards from it, when these two
prominences are large.

Pfitzner (ibid. p.215) failed to find an example;
Sewell found six in his Ancient Egyptian series.

Krause (30, p.133) does not give the frequency, but
states that it articulates with the posterior end of the
sustentaculum tali.

The Lewis tali presented no instance of this facet as
it is described, and no undoubted case was found among the
Australian bones.
The Anterior and Middle Cuneiforms

These two facets lie obliquely on the under surface of the head and neck of the talus; they are usually confluent but the line of junction is indicated by a ridge and, frequently, by a notch on the postero-lateral side.

In a number of cases the line of junction between the two is indistinguishable and a single long facet is thus produced. Small (136, p.33) found this to be so in 38 of ancient Egyptian bones.

Keane's description (35, p.133) is that the anterior facet can fuse (zusammelfliessen) with the middle one in 50% or be wanting (gänzlich fehlen) in 7% of cases. He gives the frequency of occurrence of a groove, sulcus interarticularis tali accessorius seu anterior, separating the two facets as being 16%.

Laidlaw (336, p.137) states that the corresponding anterior facet on the calcaneus is present as a separate entity in 33% of bones and is partially or completely confluent with the middle facet in 33%. The anterior facet on the calcaneus was completely absent in 7 out of 750 bones.

I have divided the Australian and Leeds tali into 4 groups:-- with the two facets completely fusi, where there was a definite ridge, doubtful cases, cases where there was a distinct sulcus between the facets. In a few cases where there was no dividing line the single facet present was small enough to suggest that the anterior facet was absent, but it was impossible to be certain on this point. The numbers of bones in each group are shown below:

<table>
<thead>
<tr>
<th>Degree of Fusion of Anterior and Middle Cuneiforms</th>
<th>Australian</th>
<th>Leeds O. R.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Complete</td>
<td>Complete</td>
</tr>
<tr>
<td>No. of Bones</td>
<td>60=43%</td>
<td>20=23%</td>
</tr>
<tr>
<td>No. of Pairs</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>No. of Individuals</td>
<td>41=39%</td>
<td>41=39%</td>
</tr>
<tr>
<td></td>
<td>Ridge</td>
<td>Ridge</td>
</tr>
<tr>
<td></td>
<td>71=51%</td>
<td>43=53%</td>
</tr>
<tr>
<td></td>
<td>Sulcus</td>
<td>Sulcus</td>
</tr>
<tr>
<td></td>
<td>present</td>
<td>present</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>11=13%</td>
</tr>
<tr>
<td></td>
<td>doubtful</td>
<td>doubtful</td>
</tr>
<tr>
<td></td>
<td>cases</td>
<td>cases</td>
</tr>
<tr>
<td></td>
<td>7=5%</td>
<td>7=3%</td>
</tr>
<tr>
<td></td>
<td>TOTAL</td>
<td>TOTAL</td>
</tr>
<tr>
<td></td>
<td>183</td>
<td>57</td>
</tr>
</tbody>
</table>

It will be seen that the fusion of the two facets is more complete in the case of the Australian tali, while the figures obtained for the Leeds specimens conform more to those quoted above.
The normal shape of the anterior and middle calcaneal facets together is figure of eight, a slight constriction being present in the region of the interlocking ridge between the two facets. The middle facet is slightly concave from before backwards in the majority of the bones which I have examined; the anterior one is usually flatter.

When the two facets are completely fused, the single facet so formed is gently convex from end to end but may be flat or slightly concave from side to side. In such cases it is frequently prolonged backwards onto the under surface of the ridge which runs forwards from the medial tuberole at the medial end of the sulcus tali, and this part is concave in the direction of the long axis of the facet.

This prolongation onto the under surface of the ridge is frequently pronounced in the Australian specimens.

Fig. 33 illustrates the condition as it occurs in two of the Australian tali and, also, the only Australian bone in which the anterior and middle facets were separated by a sulcus.

If, as seems more than probable, the foot of the Australian Aborigine is subjected to a wide range of movement, this will provide an adequate explanation of the greater degree of fusion of the facets on the talius of that race. The prolongation of the facet backwards will occur as a result of strong inversion of the foot.
The Salient Tali

No differences were noted between the Leeds and the Australian tali in regard to this salient except those resulting from differences in regard to the posterior and middle calcanean facets. The outcome of the variations in shape of these facets is that the salient tends to become progressively narrower towards its medial end in the Australian, while in the case of the Leeds bones it often narrows and then widens again at its medial end.

The Lateral Part of the Posterior Process

It has already been noted that the greatest breadth of the posterior calcanean facet is frequently situated near its medial end, and that this is more frequently the case in the Leeds series of bones, 30% as opposed to 10% of the Australian series.

This can be accounted for by the presence of two conditions, the spreading forward of the articular surface which occurs in the antero-medial part of the facet and a projection backwards of the articular surface onto the under surface of the lateral part of the posterior process.

The former condition is more frequent in the case of the Australian tali and accounts for most of the cases in which the breadth of the facet is greatest at its medial end.

The posterior projection mentioned is much more frequent in the Leeds than in the Australian bones, and accounts for most of the cases where the breadth of the facet is greater towards the medial side than in the middles in the former series. It is present in over 50% of the Leeds tali and in only about a dozen of the Australian specimens, and is much less marked in the latter.

Examples are shown in fig. 63 (overleaf) to illustrate the posterior projection as it occurs in the Leeds bones and the usual appearance of the Australian bones.

It will be seen that the posterior borders of the posterior calcanean facets of the two Australian specimens are nearly straight, and this is the case in the large majority of the Australian tali. The reason for the difference as regards the articular facets would appear to be a difference in the size of the lateral part of the posterior process in the two races. The process is much more prominent in the Leeds specimens.
Fig. 33, to illustrate the difference in size of the lateral part of the posterior process in the Australian and Leeds tali, and the relationship which it bears to the backward prolongation of the articular surface of the posterior calcanean facet, found frequently in the Leeds series of bones.
The Os Trigonum

The explanation of the varying size of the lateral part of the posterior process raises the question of the os trigonum about which so much has already been written, but little can be said about it here. The relatively small size of the lateral part of the process in the Australian tali may be due to either a greater frequency in the occurrence of a separate ossicle which has not been preserved, or to a more complete fusion of the ossicle with the body of the bone than is the case in the heels bones.

Which of these explanations is the correct one, I have found it impossible to say. Some of the Australian tali bear markings which may have been caused by contact with a separate ossicle, but which may equally well be part of the insertion of the posterior talo-fibular ligament. Also, a separate os trigonum may be united to the talus by means of fibrous tissue and so may not produce an articular facet.

Fig. 70, a series of bones selected from among the native tali to illustrate various stages of fusion of the os trigonum. No. 74 shows a large lateral part of the posterior process, but there is no line of demarcation between it and the rest of the bone; in no. 19 a distinct line is visible; in no. 30 there is still a firm bony union, but there is a furrow present; in no. 32 there is a freely movable os trigonum.
Position of the Foot

It would appear that the foot of the Australian native is normally less turned out than in the European races. Quarry Wood refers to illustrations in Spencer and Gillen (61) to support this view, and Klaatsch makes the statement that the female Australian native stands with the foot parallel.

Wood (53, p.357) found the angle of torsion of the tibia to be small in the Australian (17°), as against a larger angle in the European adult, its absence in infants (Le Damany) and a negative angle in the case of the Anthropoides (Klaatsch). Le Damany associated the degree of torsion with the habit of turning out the feet so as to improve the base of support when standing, and Wood associated the small angle found in the Australian with the straight position of the foot.

I have been unable to demonstrate any changes in the form of the Australian talus which can be said to be the result of the straight position of the foot in that race. If it affects the obliquity of the long axis of the posterior calcaneal facet of the talus, as is suggested by Fick (13a, p.423), the effects are masked by other features such as the results of forced inversion of the foot.

Inversion and Eversion of the Foot

The greater extent of the articular surfaces of the posterior calcaneal facet and of the head of the talus, the more pronounced curvature of the head and the greater extent and degree of fusion of the anterior and middle calcaneal facets, found in the Australian in comparison with the Sesia tali, all suggest that the Australian native possessed a wide range of movement at the talo-calcanean and talo-calcaneo-navicular joints.

The backward prolongation of the middle calcaneal facet, the greater frequency of the changes described as occurring in the antero-medial part of the posterior calcaneal facet, the less frequent occurrence of the facies externa accessoria corporis tali, and the greater angle of the neck in a horizontal plane found in the Australian all suggest that the most pronounced movement at the joints mentioned must have been inversion. This is supported and accounted for by the habit of squatting adopted by the
Australian natives. The adoption of the staggered sartorial position may possibly be the result of a developmental tendency towards inversion of the foot, but, if so, that tendency is exaggerated by the habit and the talus shows evidence of changes which can only be the result of habit.

W. A. Thomas (52, p.21) writes that "the track left by the foot of an Australian is said to differ markedly from that of a European; the heel is narrow and the fore part of the foot comparatively broad; the inside side of the foot bends inward in a peculiar way, a formation which may possibly be due to the method of climbing trees, of which a description is given in Chap. IV".

The bending inward of the medial side of the foot may possibly be produced by habitual inversion, since that movement raises the medial side of the foot. If this is so, then Thomas' description suggests that the foot of the Australian is in a permanent state of slight inversion.

The Tibial Angle and the Trochleo-Basal Angle

Bryce (7, p.237) describes one stage of the development of the talus as follows: "...the talus undergoes a rotation in the sense that the lateral border of the future trochlea sinks, and the medial rises.... At the tenth week the axis of the ankle joint is still oblique, and the trochlea has a slight medial inclination.... This primitive position, characteristic of the Anthropoid foot, persists in some of the lower races of mankind; out in the higher races a further rotation occurs, only completed when the child begins to walk, by which the axis of the ankle-joint becomes strictly transverse....".

Volkov (57) has expressed the slope of the ankle joint as a tibial angle measured between the coronal axis of the trochlear facet and a plane at right angles to the long axis of the tibia. Some of his results are shown below:

<table>
<thead>
<tr>
<th>Tibial Angle (Volkov)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sibboon 27°</td>
<td>Australian 1,7°</td>
</tr>
<tr>
<td>Chimpanzee 25,3°</td>
<td>European 3°</td>
</tr>
<tr>
<td>Gorilla 25,7°</td>
<td>Japanese 3°</td>
</tr>
</tbody>
</table>

If the difference between the heights of the trochlea on its medial and lateral sides is great, it does not of
necessity mean that the foot is inverted, or that the axis of rotation of the ankle joint is oblique. The heights of the trochlea on either side can vary without altering the position of the talus, provided there is a similar slope on the lower surface of the tibia.

The angles given by Volkov for European and Australian tibias are of interest because the difference between the tibial angles of the two races is practically the same as the difference between their trochlea-osseous angles for the Ramsay Smith Australian talus and the Leeds tali, i.e., 1.3°.

The difference between the trochlea-osseous angles in each series of talus does not, therefore, imply any inversion or eversion of the foot as a direct result of the shape of the talus, since the slope of the articular surface of the tibia counteracts that of the trochlea. The axis of rotation of the joint remains the same in direction in the two races.

If this is so, then the essential difference between the two races, in regard to the heights of the trochlea, is that the fibula plays a greater part in the formation of the ankle joint in the Australian than in modern civilised races. To corroborate this, it is found that the lateral malleolar facet of the Australian talus is not only more prominent but deeper from upper edge to apex than is the malleolar facet of the Leeds Dissecting Room tali.

Harrower (22, p.238) attempts to correlate reduction of the little toe with "the reduction of the fibula which can be traced in all stages throughout the animal kingdom". It seems possible that the large size of the lateral process of the Australian talus may be associated with the broad anterior part of the Australian foot referred to by Thomas. Whether this can be linked up with the position of the malleoli, I am not prepared to say.

Flexion and Extension

The part of the trochlea which is in contact with the under surface of the tibia has a short and highly curved appearance in the Australian talus and suggests a wide range of movement at the ankle joint. The prolongations and accessory facets or smoothings indicate that strong dorsiflexion must have been frequent. The presence of the post-trochlear facet suggests a similar state of affairs in
regard to extension, the inferior transverse ligament being
forced back against that area and the groove which
separates it from the trochlea, but the displacement of the
medial malleolar facet forwards in these cases introduces
a complication. It is possible that, if the medial
malleolus is placed far forwards, the position of the
ligament might be such as to cause the facet and groove
as a result of moderate extension of the ankle joint.

Strength of the Joints

The foot of the Australian Aborigine possesses a wide
range of movement but the joints are strong, as they must
be under natural conditions. The markings made by
ligaments on the talus are all pronounced; Quarry Wood has
shown that the medial malleolus is long and the extent of
the lateral malleolar facet and size of the lateral process
are evidence of strength on the lateral side.

There is no evidence of undue narrowing of the
trochlea posteriorly, so as to allow too much play at the
ankle joint during extension, while the widening of the
trochlea at its anterior end is far forward and is
accommodated by the bevelling present on the anterior
border of the medial malleolus.

The deep groove on the surface of the trochlea must
serve to compensate for any tendency to instability which
might result from the slight slope of the articular surface
of the tibia.

The Arches of the Foot

The slightly smaller vertical angle of the neck and
the slightly smaller length-height index of the Australian
tali compared with the Leeds specimens both suggest that
the long arch of the foot must have been slightly less well
developed in the Australian than in modern civilised races.

The smaller angle of torsion of the head of the talus
of the Australian suggests similarly that the transverse
arch was also slightly less developed in that race. Any
appreciable amount of inversion of the foot will, however,
produce a degree of concavity of the sole of the foot and
will also tend to reduce the amount of torsion of the head
of the talus. It is difficult to separate the effects of
of strong inversion of the foot and of the presence of a
well developed transverse arch.
(1) The minimum number of bones required to yield a reasonably reliable average was found to be about thirty for most measurements and indices of the talus. Average figures based on a smaller number of measurements are open to suspicion and may be misleading.

(2) Absolute measurements of the talus of the Australian Aborigine show it to be smaller all round than the Leeds specimen with which it has been compared.

(3) It is relatively broader than the average Leeds bone and this is mainly due to the greater size and prominence of the lateral process in the case of the Australian. There are, however, other factors which may increase the length-breadth index, such as the presence of a pronounced ridge on the medial surface of the body of the talus, or a large angle of the neck in a vertical or horizontal plane.

(4) It is slightly flatter than the Leeds bones, and the length-height index varies, in both the Australian and the Leeds series, along with the angle of the neck measured in a vertical plane. Both the index and the angle are slightly smaller in the case of the Australian, and it is suggested that a large angle of the neck in a vertical plane is to be associated with a well developed longitudinal arch of the foot.

(5) The angle between the axes of the neck and of the trochlea is large in the Australian. This can be accounted for to a large extent by the adoption by that race of an exaggerated sartorial position when at rest and the consequent habitual strong inversion of the foot. The angle in modern civilised races is about 13° on the average.

(6) The trochlea is relatively short in the case of the Australian but, though it appears narrow on account of the projecting lateral process, there is no appreciable difference between its relative breadth and that of the Leeds bones used for comparison. This is in opposition to the usually accepted view that the trochlea is broad in the higher races to increase stability.

(7) The difference between the anterior and posterior transverse measurements of the trochlea is pronounced in the Australian tali, but this is due to an increase of the
or...rath anteriorly rather than to any great amount of narrowing posteriorly. The large measurement anteriorly in the Australian is associated with the large amount of deviation of the neck, with the pronounced concavity of the medial malleolar facet and with the bevelling of the anterior margin of the medial malleolus described by Quarry Wood.

(3) The heights of the medial and lateral parts of the trochlea above the basal plane are, on the average, equal in the Australian, while the medial height is the greater in the case of the Leeds bones; the trochlea-basal angle corresponds and is practically nil in the Australian. The usual statement made is that the lateral border is the higher.

(9) The longitudinal groove on the trochlea is distinctly deeper in the Australian than in the Leeds tali; it is also more clearly defined and lies nearer to the medial margin of the trochlea in the former bones.

(10) A post-trochlear portion of the articular surface is described, which is more frequent and more pronounced in the Australian tali. It is present in bones where the medial malleolar facet does not pass far back and it is in contact, during extreme extension of the ankle joint, with the inferior part of the posterior tibio-talar (inferior transverse) ligament which would appear to be strongly developed in the Australian.

(11) The facies intermedia is well marked in the Australian, again suggesting that the abovementioned ligament is well developed in that race.

(12) Anteriorly, the trochlea of the Australian talus shows a medial and a lateral prolongation; beyond the prolongation on the lateral side there is very frequently a lateral smoothing or facet which is in contact with the edge of the tibia during extreme flexion of the ankle joint. Much less frequently there is a smoothing of the neck at its medial side.

The two prolongations of the trochlea and the lateral smoothing or facet are associated with strong dorsiflexion of the ankle joint, but the origin of the smoothing on the
medial side is doubtful in the absence of the soft parts. It is not due to direct contact with the margin of the tibia. These conditions are much more frequent in the Australian than in the Leeds tali.

13) The medial malleolar facet appears to be placed further forward and is relatively slightly longer in the Australian than in the case with the Leeds specimens.

11) It is concave to a much greater extent in the Australian and its anterior part faces inward, upward and slightly outward in that case. The curvature of its surface in an antero-posterior direction corresponds to the bevelling of the anterior margin of the medial malleolus described by Quarry Wood. Its shape would seem to be the result of flexion of the ankle joint, and not rotation as he suggested.

15) The increased relative length of the medial malleolar facet in the Australian is associated with an encroachment of the articular surface on the surface of the bone in front of it. Various stages of this can be seen on different bones, showing that the increased length of the facet is due to habits rather than to development.

18) The lateral process and the lateral malleolar facet are both large in the Australian compared with the Leeds tali, and this applies to both the projection laterally and to the depth of the facet measured from its apex to the lateral margin of the trochlea.

17) The curvature of the head of the Australian talus is pronounced and the relative length of the head is greater than in the case of the Leeds tali examined. Both of these factors must facilitate a greater range of movement at the talo-calcaneo-navicular joint in the Australian and so increase the power of inversion and/or eversion in that race.

13) The angle of torsion of the head of the talus does not differ greatly in the two races; it is slightly smaller in the Australian. It is suggested that this angle varies with the degree of development of the transverse arch of the foot, and it is possible that, in the Australian, inversion of the foot has counterbalanced *combined with the presence of a large horizontal angle of the neck.
the effects of a rather low transverse arch on the angle.

(19) No difference was demonstrated between the two races in regard to the angle between the long axes of the posterior calcaneal facet and of the trochlea.

(20) The posterior calcaneal facet is relatively longer in the Australian than in the Leeds talus. It is also broader and there is no appreciable difference between the length-breadth indices of the facet in the two races except as a result of the inclusion in the osseous of the articular area on the under surface of the lateral part of the posterior process. This area is larger in the Leeds specimens and goes hand in hand with the size and prominence of the lateral part of the posterior process.

(21) It is possible that the posterior calcaneal facet is fundamentally narrower and longer in the Australian than in modern civilised races, but that this is masked in the case of the Australian by changes resulting from habitual inversion of the foot.

(22) The length-depth indices of the posterior calcaneal facet are also similar in the two races. Increased range of movement is provided for in the Australian by an increase in the size of the facet, rather than by an increase in the curvature of the articular surface.

(23) The facies externa accessorio corporis tali is more frequent and more pronounced in the Leeds than in the Australian series. It is the result of splaying of the foot, and not inversion as was stated by Sewell.

(24) An alteration in the curvature of the antero-medial part of the posterior calcaneal facet also occurs, and is accompanied by a "spreading" of the articular surface forwards. These changes are more frequent in the Australian than in the Leeds talus and are due to strong inversion of the foot.

(25) The anterior and middle calcaneal facets are more frequently and more completely fused in the Australian than in the Leeds bones. This can be explained as the result of a greater amount of movement at the talo-calcaneonavicular joint in the Australian.
The posterior end of the middle calcanean facet extends further back, in the Australian, along the ridge which runs forwards from the medial tubercle. This prolongation back must occur as a result of strong inversion of the foot.

The Australian talus is formed so as to permit a wide range of movement of the foot, particularly inversion, but there is no suggestion of lack of strength in the joints, or of any want of stability.

Most of the differences between the Australian talus and those with which they have been compared can be attributed to habits and the use to which the foot is put after birth. Exceptions to this would include the small size of the Australian talus, the depth of the groove on its trochlea, the slightly low length-height index, the prominence of the lateral process, the straight posterior border of the posterior calcanean facet and, possibly, the position of the medial malleolar facet.

The cast of the Spy talus examined resembles the Australian type of bone in that the horizontal angle of the neck is large, the medial malleolar facet extends far forwards, a concave posterior portion of the medial margin of the trochlea exists and a post-trochlear facet is present; the lateral malleolar facet, the lateral process and the medial tubercle are all large, and the posterior border of the posterior calcanean facet is straight.

It differs from the Australian bones mainly in size, and more particularly in regard to the bulk of the body of the bones; the trochlea is distinctly long and the groove on its surface is shallow. The trochlea has a square appearance, because of a poorly marked facies interna, but, in spite of this and the shallow groove, has a distinct resemblance to the Australian trochlea on account of the appearance of displacement of the medial malleolar facet forwards.

Various authors refer to certain features which appear on the talus of savage races as being simian.

It is true that these features do appear on simian tali and are to that extent simian, but the apparently obviously simian features of the adult Australian talus
(the large angle of the neck in a horizontal plane and the concomitant changes in the medial malleolar facet, in the antero-medial part of the trochlea and in the calcaneous facets) are probably the result of the mode of using the foot after birth. Further, an inspection of a number of simian tali shows that not only is the angle of the neck of the talus large but the neck is set onto the body of the bone well to its medial side, a feature which does not appear on human tali.

Simian tali are definitely flat in proportion to their length or breadth, but the Australian tali are only slightly so in comparison with the Leeds tali, while the Spy talus is definitely high.

The medial part of the trochlea of the talus is low and the tibial angle is large in the Simiidae, but the Australian differs only to a slight degree from the European in these respects.

Evidence as to the size of the lateral process of the talus in the Simiidae is not sufficiently conclusive to allow of comparisons with regard to this characteristic feature of the Australian and prehistoric tali and I have been unable to obtain sufficient material to investigate the point by means of measurements.
<table>
<thead>
<tr>
<th>Table of Average Measurements, Latinc and Calea</th>
<th>Australian Leeds D.R.</th>
</tr>
</thead>
<tbody>
<tr>
<td>LENGTH OF TALUS</td>
<td>33.3 mm</td>
</tr>
<tr>
<td>BREATH OF TALUS</td>
<td>30.2 mm</td>
</tr>
<tr>
<td>HEIGHT OF TALUS</td>
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<td>LENGTH-BREADTH INDEX OF TALUS</td>
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<td>LENGTH-HEIGHT INDEX OF TALUS</td>
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<tr>
<td>ANGLE OF TALUS IN A HORIZONTAL PLANE</td>
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<tr>
<td>DEPTH OF BREA(0N ON TROCHLEA</td>
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</tr>
<tr>
<td>LENGTH OF TALUS ALONG ITS AXIS</td>
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</tr>
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<td>&quot;TOTAL&quot; LENGTH OF TROCHLEA</td>
<td>32.8 mm</td>
</tr>
<tr>
<td>BREATH OF TROCHLEA</td>
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</tr>
<tr>
<td>RELATIVE LENGTH OF TROCHLEA</td>
<td>31.3%</td>
</tr>
<tr>
<td>RELATIVE &quot;TOTAL&quot; LENGTH OF TROCHLEA</td>
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</tr>
<tr>
<td>RELATIVE BREA(0N OF TROCHLEA</td>
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<td>BREATH OF TROCHLEA RELATIVE TO LENGTH OF TALUS</td>
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<td>LENGTH-BREADTH INDEX OF TROCHLEA</td>
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<td>MEDIAL HEIGHT OF TROCHLEA</td>
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<tr>
<td>LATERAL HEIGHT OF TROCHLEA</td>
<td>27.3 mm</td>
</tr>
<tr>
<td>DEPRESSION BETWEEN MEDIAL AND LATERAL HEIGHS</td>
<td>3.0 mm</td>
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<tr>
<td>TROCHLEA-BASAL ANGLE</td>
<td>3.8°</td>
</tr>
<tr>
<td>DISTANCE BETWEEN ANTERIOR END OF MEDIAL MALL SORAL</td>
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<td>DISTANCE BETWEEN POSTERIOR END OF MEDIAL MALL SORAL</td>
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<tr>
<td>LENGTH OF MEDIAL MALL SORAL</td>
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<tr>
<td>ANGLE OF TORSION OF HEAD</td>
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<tr>
<td>LENGTH OF HEAD ALONG SURFACE</td>
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<tr>
<td>BREADTH OF HEAD</td>
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<tr>
<td>DISTANCE BETWEEN MEDIAL MALL SORAL AND BREADTH OF HEAD</td>
<td>10.0 ; 61.3 100 ; 39.1</td>
</tr>
<tr>
<td>RELATIVE SURFACE LENGTH OF HEAD</td>
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<td>RELATIVE DEPTH LENGTH OF HEAD</td>
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<tr>
<td>PROJECTION OF LATERAL PROCESS BEYOND MARGIN OF TROCHLEA</td>
<td>31.5°</td>
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<td>DEPTH OF LATERAL MALL SORAL</td>
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<td>RELATIVE LENGTH OF POSTERIOR CALCANEAN SACR</td>
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<td>LENGTH OF POST. CALC. SACR. REL. TO BREADTH OF TROCH</td>
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<tr>
<td>RELATIVE BREA(0N OF POSTERIOR CALCANEAN SACR</td>
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<tr>
<td>A. USING BREATH OF TALUS</td>
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<td>B. USING BREADTH ACROSS MIDDLE OF LONG AXES</td>
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<tr>
<td>LENGTH-BREADTH INDEX OF POSTERIOR CALCANEAN SACR</td>
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<td>A. USING BREA(0N OF TALUS</td>
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<tr>
<td>B. USING BREADTH ACROSS MIDDLE OF LONG AXES</td>
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<td>DEPTH OF CURVATURE OF POSTERIOR CALCANEAN SACR</td>
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<tr>
<td>LENGTH-DEPTH INDEX OF POSTERIOR CALCANEAN SACR</td>
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<tr>
<td>ANGLE BETWEEN LONG AXES OF POSTERIOR CALCANEAN SACR AND LONG AXES OF TROCHLEA</td>
<td>45.7°</td>
</tr>
</tbody>
</table>
Methods of taking Tracings and Instruments used

The line drawings of the upper aspect of the talus used in the foregoing as illustrations have all been taken from tracings made by means of a pantograph with an eye-piece working over a glass plate, the eye-piece being provided with a pinhole and cross wires to ensure accuracy of outline. The bone concerned was placed on a basal plane which lay parallel to the glass plate over which the eye-piece moved.

It was found, however, from a comparison between measurements made on the tracings and measurements of the bones, that a momentary lack of concentration on the work of making the tracing could produce an error of about 1 mm. These tracings have, therefore, not been used for the purpose of obtaining any measurements.

The tracings of the outlines of articular surfaces have been made by means of a perimeter and are more accurate.

In order to hold the talus in the correct position to obtain tracings in any given plane it was found necessary to devise a special clamp. The essential part of this consisted of a stout brass plate which acted as a basal plane to which the bone could be fixed, and lines were ruled on this to facilitate the adjustment of the bone in any given position.

A strong vertical rod was fixed to the edge of the plate at right angles to its surface and the free end of the rod was shaped to fit already existing apparatus so that the plate could be swung or rotated into any given plane. A loose arm was fitted to slide up and down the rod, whilst a screwed collar on the rod served to press down the arm against the bone on the plate and fix it in position.

To overcome the difficulty presented by the irregular surface against which the arm had to press, an inverted U was set in the end of the arm so as to be free to swing from side to side and so adjust itself to irregularities of the bone and hold it firmly.

The plate was adjusted in the required position by means of spirit levels, and a tracing of its surface was taken along with each tracing of a bone so that the tracing might be properly oriented or measurements made from it.
Actual measurements of the talus were, for the most part, carried out by means of a Columbus gauge of the type illustrated below.

Fig. 71

The characteristics which render this instrument of special use in dealing with the talus are as follows:

(1) The blades, $E$ and $E'$, for taking external measurements are thin, so as to fit into hollows such as the sulcius for the flexor hallucis longus tension, and the edges are straight so that measurements in projection can be rapidly made by placing the points of the blades on the surface supporting the bone and bringing their edges against the desired points on the bone.

(2) A depth gauge, $D$, is provided.

(3) The instrument can be obtained graduated in both millimetres and inches and two verniers, $V$ and $V'$, give readings to $\frac{1}{100}$th mm. and $\frac{1}{16}$th ins. The same scales refer to external, internal and depth measurements.

(4) The instrument is of suitable size, the movement of the blades being about $10$ cm.

A fine adjustment screw, $T$, is also provided, but is unnecessary for ordinary work and can be easily removed.

The depth gauge proved to be unsuitable for work on the talus owing to the slith of the curved surfaces dealt with, in contrast to the slith of the end of the instrument. This difficulty was surmounted by fixing a bar, $B$, at right angles to the sliding rod, $S$. This bar was then filed to an edge which was in line with the point of the rod.

Fig. 72

Measurements of depth were thus taken from a line joining the points of contact between the bar and the margins of the hollow to be measured, as in Fig. 72.
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