THE AUSTRALIAN TIBIA.

Anthroposcopic and anthropometric observations upon 236 Australian tibiae, together with a comparison with the tibia of other races, historic and prehistoric.

Thesis for the Degree of M.D. 1916.

by

W. Q. Wood, M.B., Ch.B.

I N D E X.

INTRODUCTORY.

The tibia, from the anthropological point of view, is one of the most important of the long bones. Not only does it vary in length to a remarkable degree, but it presents numerous features, in the degree of development of which there is a marked difference between the tibia of the more primitive races and the European tibia. In addition, there is a distinct resemblance between these features in the bones of prehistoric man and in the primitive races. A considerable amount of work has already been carried out on the tibia so that materials for comparison are abundant.

In the case of the Australian tibia, although it presents numerous features of special interest, the work done has been only fragmentary. In no instance has a systematic examination of this bone been made. Arthur Thomson of Oxford in 1889 referred to the presence of those appearances which are produced by the attitude of squatting and to the relationship of these features to platycnemia. The number of bones examined by him was fourteen. Hermann Klaatsch of Breslau in 1910 discussed the resemblance between the Australian tibia and that of the Orang and of Homo Aurignacensis. Beyond these investigations, very little work of any importance has been done.

In the present instance I have been very fortunate, owing to the kindness of Professor Arthur Robinson, in obtaining access to the Australian tibiae in the Anatomical Museum of Edinburgh University. The collection is large and the majority of the bones are in good condition. A large number of the specimens were presented to the Museum by Dr W. Ramsay Smith and they have been mainly derived from the Northern territory. In the present investigation mutilated specimens were rejected but a total of 236 bones were available for examination. The advantage of examining such a large number is, naturally, to neutralise fallacies due to individual variations, and in any anthropometric investigation it is found that such variations are very common and may exist to a remarkable degree.

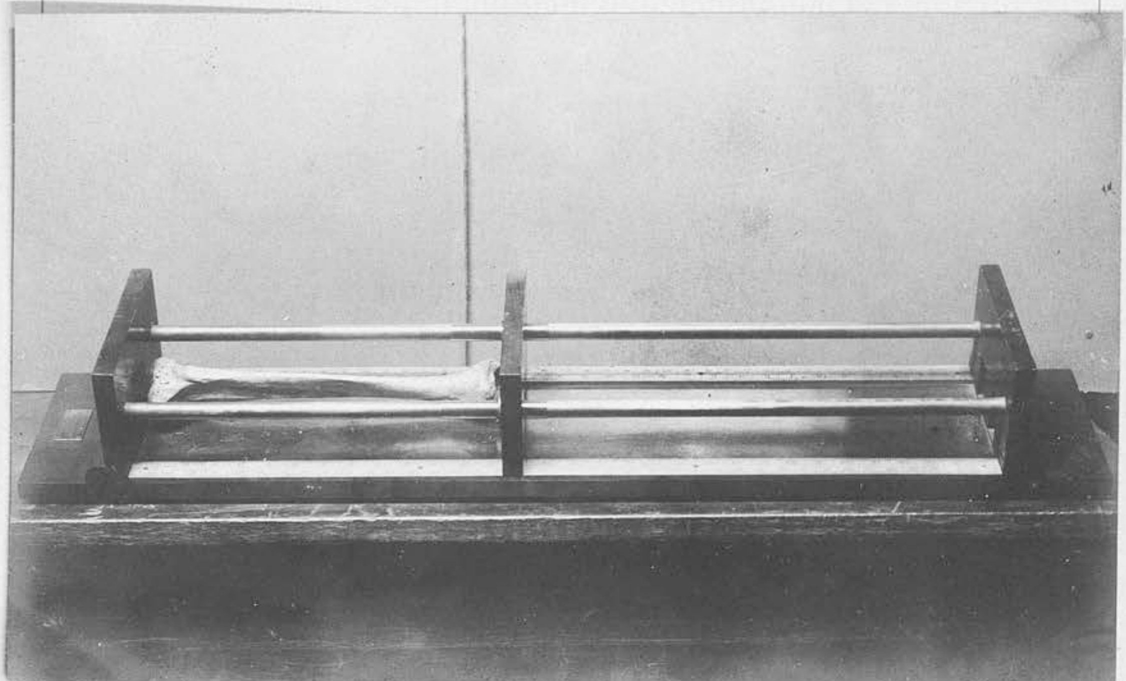


Fig. 1.

Hepburn's Measuring Board. The board in contact with the malleolus has the power of sliding on the two horizontal rods. The board at each end is fixed. The one on the right side of the photograph shows recesses for the reception of processes such as the malleolus or the intercondyloid eminence.

TECHNIQUE.

I give here a brief account of the technique adopted. Where it is necessary, a fuller description will be given in connection with individual sections. The methods employed were mainly those recommended by Rudolf Martin in his Lerbuch der Anthropologie (14).

1. Length of Tibia. The distance of the superior articular surface of the lateral condyle from the tip of the medial malleolus. In the measurements of length the instrument employed wherever possible was Hepburn's Measuring Board which is illustrated in Fig.I. This consists essentially of two vertical boards, one of which is fixed to a floor-piece on which is a millimetre scale, and the other of which slides on two horizontal rods. The bone is placed on the floor-piece with one end touching the fixed of the two vertical boards; the sliding-board is then brought into contact with the other end and the length read off on the scale. On each of the two vertical boards there are small recesses into which processes such as the intercondyloid eminence or one of the condyles of the tibia can be fitted and the measurement in that way taken directly from the neighbouring articular surface.

1a. Greatest length of Tibia (Spino-Malleolar length)./

length). The distance between the most prominent part of the intercondyloid eminence and the tip of the medial malleolus.

1b. Length of Tibia. The distance from the mid-point of the margin of the medial superior articular surface to the tip of the medial malleolus. The advantage of this measurement lies in the fact that it can be compared with measurements in the living bone or in the articulated skeleton.

2. Condylo-astragaloid length of Tibia. The distance of the mid-point of the articular surface of the medial condyle from the base of the medial malleolus where the latter articulates with the superior surface of the talus. For this measurement and the next the instrument known as the Parallelograph was used. A description of this instrument will be found below.

2a. Joint-surfaces distance. The distance of the superior articular surface from the least prominent part of the inferior articular surface. In many cases this measurement was the same as the preceding, but in some bones a less prominent point on the inferior surface was found than that which is situated at the base of the malleolus. In some cases this was only a short distance lateral to the malleolus, in others it was situated at the extreme lateral margin/

margin of the articular surface.

3. Greatest Breadth of the Proximal Epiphysis. The distance of the most projecting points on the sides of the medial and lateral condyle from each other. The bone is laid with its posterior surface on the floor-piece of the measuring board in such a way that it fits closely with its lateral side to the fixed board; the sliding board is then made to touch the medial condyle.

4. Greatest Sagittal Diameter at the level of the Tuberosity. The distance between the most prominent part of the tuberosity and the mid-point of the posterior surface in the same plane. This measurement was made with Callipers.

5. Smallest Transverse Diameter at the level of the Tuberosity. A line from the medial to the lateral margin at the level of the tuberosity. This also was made with Callipers.

6. Greatest Breadth of Lower Epiphysis. The distance between the most projecting (most medial) point on the medial malleolus and the lateral surface of the lower epiphysis. The bone is laid on the measuring board with its lateral surface (and the two prominences which surround the incisura fibularis) close up to the fixed end; the sliding board touches the medial malleolus.

7. Sagittal Diameter of the Lower Epiphysis. The distance/

distance between the anterior and posterior borders of the lower epiphysis in the median plane of the bone on a line at right angles to its long axis. Callipers employed.

8. Sagittal, i.e. the greatest, Diameter of the Middle of the bone. The distance between the anterior crest and the posterior surface measured in the middle of the bone. The mid-point was measured from the Spino-Malleolar length (1a) and the place marked with a pencil. Callipers employed.

8a. The same measurement but taken at the level of the nutrient foramen.

8b. The same measurement but about 3 - 4 c.m. below the nutrient foramen at the place where the linea poplitea cuts the medial margin.

9. Transverse Diameter of the Middle. The distance between the medial margin and the interosseous crest measured in the middle of the bone at the place where the sagittal diameter was taken.

9a. Same measurement but at the level of the nutrient foramen.

9b. Same measurement but at the point where 8b was taken.

10. Circumference of the Diaphysis. The circumference in the middle of the bone. Tape measure employed.

10a. Same measurement but at the level of the nutrient foramen.

10b. Smallest Circumference of the Diaphysis, wherever it is. This is usually in the lower third of the bone at the place where the crista anterior begins to disappear - approximately 10 c.m. from the tip of the medial malleolus.

11. Curvature of Tibia. The distance of the highest point of the curvature of the crista anterior from a straight line which is drawn between the two ends of the curve.

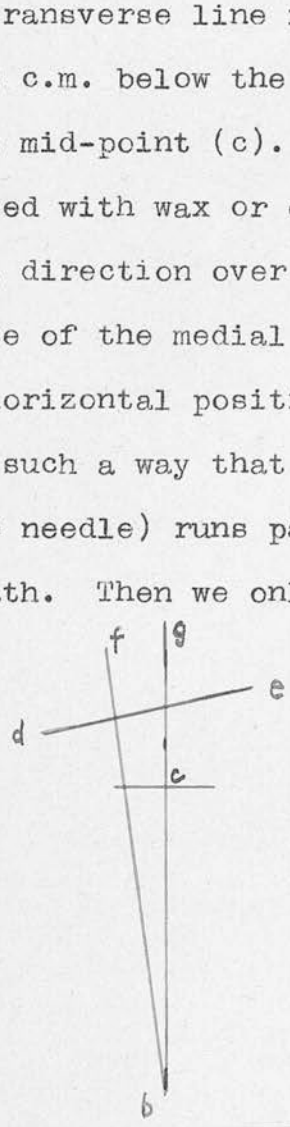
In the majority of cases the anterior border of the tibia presented a curve convex forwards in the proximal two-thirds of the diaphysis. The ends of this curve were marked on the paper by means of the Parallelograph, the bone being clamped in the horizontal position with its lateral surface directed upwards. The curve of the crest was then traced by means of the Perigraph - which will be described later - and the distance measured between the summit of the convexity and the line joining the two ends of the curve - i.e. the chord of the curve.

12. Retroversion angle. The angle which a tangent to the articular surface of the medial condyle in a sagittal direction makes with the axis of the bone taken through the middle of the diaphysis. Procedure as in No.13.

13./

13. Inclination angle. The angle which the same tangent makes with a line joining the mid-point of the articular surface of the medial condyle to the mid-point of the articular surface of the distal extremity.

These two angles were determined by the use of the Parallelograph. A pencil mark, in the first place, is made on the mid-point of the articular surface of the medial condyle (a) and on the mid-point of the inferior articular surface (b), the latter point being situated on the middle of a faintly marked ridge running in the sagittal direction. Nextly, a transverse line is taken on the lateral surface 1-2 c.m. below the tuberosity and a mark placed at its mid-point (c). A steel needle (d,e) is then fixed with wax or other adhesive material in a sagittal direction over the middle of the articular surface of the medial condyle. The tibia is placed in a horizontal position, the lateral surface uppermost, in such a way that the tangent of the condyle (i.e. the needle) runs parallel to the marble slab underneath. Then we only require to mark off the above-



mentioned points, a, b, and c, and the two ends of the needle, d and e, on a sheet of paper. The straight lines d,e and b,f are drawn through a, and b,g through c. The angles can then/

then be measured with a protractor, the angle g,h,d giving the angle of Retroversion, and f,a,d, the angle of Inclination. For the sake of simplicity 90° is deducted from each of the angles.

The so-called Biaxial angle, i.e. the angle which the morphological bone axis (b,g) and the physiological bone axis (b,f) make with one another, corresponds simply to the difference of the two angles, Nos. 12 and 13.

14. Torsion of the Tibia. The angle which the transverse axis of the superior articular surface makes with the transverse axis of the inferior articular surface. The Parallelograph is again employed. The upper transverse axis is marked by fixing a steel needle over the mid-points of the articular surfaces of the two condyles. The lower axis is marked in the same way with a needle placed at about an equal distance between the anterior and posterior borders of the articular surface. The bone having been clamped in the vertical position, the points corresponding to ends of the needles are marked on the paper with the parallelograph. The two axes are drawn in on the paper and the angle which they make with each other is the angle of torsion.

The following Indices were calculated from the above measurements:-

1/

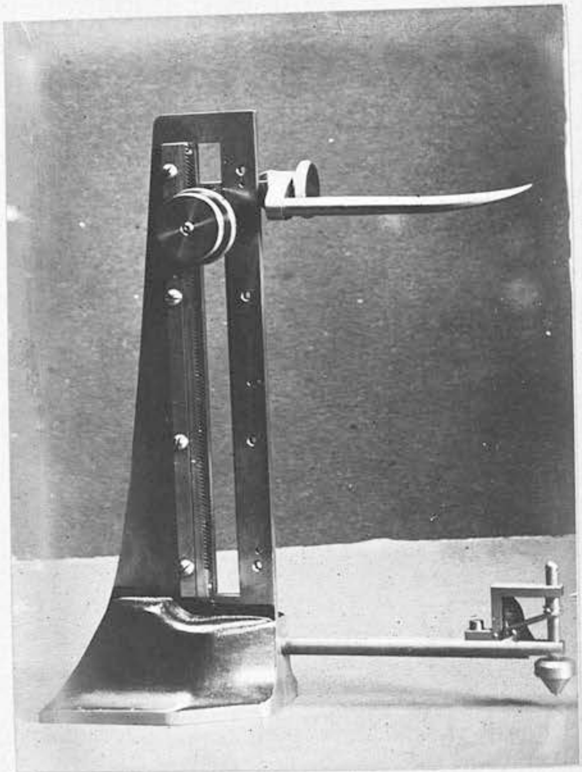


Fig. 2.

The Perigraph. In making a tracing the tip of horizontal needle is kept in close contact with the bone. The stylo underneath marks the outline on the paper.

1. Index of Transverse and Sagittal Diameters at Middle

$$= \frac{\text{Transverse diameter of Middle (9)} \times 100}{\text{Sagittal diameter of Middle (8)}}$$

2. Index cnemicus

$$= \frac{\text{Transverse diameter at for. nutr. (9a)} \times 100}{\text{Sagittal diameter at for. nutr. (8a)}}$$

3. Length-Thickness Index

$$= \frac{\text{Smallest circumference of diaphysis (10b)} \times 100}{\text{Length (1)}}$$

4. Curvature Index

$$= \frac{\text{Height of Curvature of Crista-Anterior (11)} \times 100}{\text{Chord of Curve (11)}}$$

The results of these measurements and the Indices will be found in tabular form at the end of this article.

In addition to the above, the following tracings were made in the case of each bone wherever possible:-

1. An outline of the diaphysis at the level of the nutrient foramen.

2. An antero-posterior tracing across the middle of the articular surface of the lateral condyle.

3. A transverse tracing across the middle of the same surface.

The appearances of these tracings will be discussed later. The instrument employed was that known as the Perigraph, the type being similar to the model/

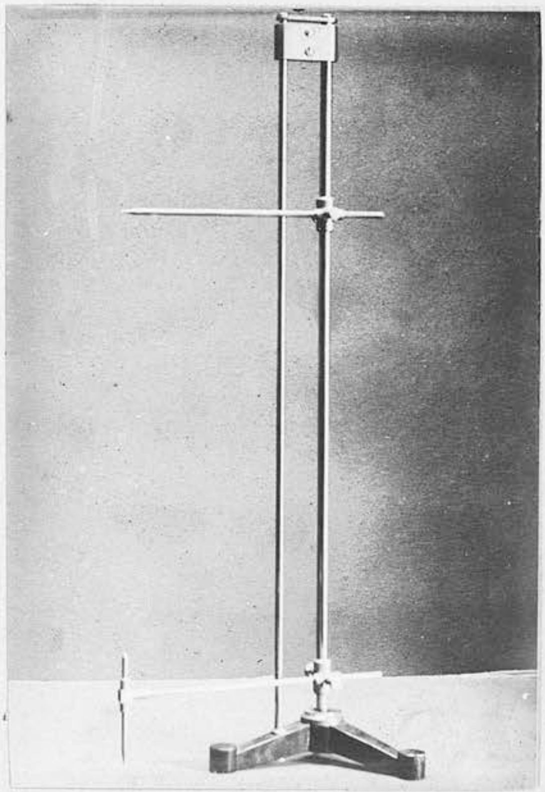


Fig. 3.

The Parallelograph. The point of the upper needle touches the bone. Both needles slide on the posterior of the two vertical rods. By having both needles of exactly the same length and maintaining them both in contact with the anterior vertical rod, the position of the point of the upper needle can be marked out accurately on the paper underneath.

model described by G. Wetzel in Zeitschrift fur Morphologie und Anthropologie, 1911. An illustration of this instrument will be found in Fig.2. It consists essentially of a steel needle which is applied to the surface of the bone at the desired level and a "writer" constructed after the fashion of a stylo pen, which makes a tracing in ink at an exactly similar point on the paper below.

The Parallelograph, which has been utilised in several of these measurements is seen in Fig.3. It consists of two horizontal needles which slide on a vertical pillar. When the point of the upper needle is applied to the bone, the lower makes a mark on the paper at an exactly similar point below.

The clamps used to hold the bones were after the patterns recommended by Wetzel and Martin.

MEASUREMENTS OF LENGTH.

It is convenient, as a general rule, to take up the consideration of the various dimensions and angles separately, and I shall follow, as far as possible the order in which the measurements are given under "Technique".

Length of the Tibia. In estimating the size of the tibia no attempt has been made to distinguish the sex of the bone. The average length as measured from the articular surface of the lateral condyle to the/

the tip of the medial malleolus in the present series was 380 m.m. The longest bone was 446 m.m. and the shortest 316 m.m.

Martin (14) gives the average length of 2000 white Americans as 365 m.m. (310-445) in the male and 345 m.m. (280-390) in the female. In the Alamann the average for the male is 373 m.m., for the female 342 m.m.; in the Naquada 365 and 355 m.m., for the Paltacalo Indian 344 and 311 m.m., and in the male Aino 331. It will be seen, therefore, that the Australian tibia shows a well-marked predominance in length over the tibia of other races, even over the tibia of the modern white individual.

The average spino-malleolar length was 386 m.m., showing an increase over measurement (1) of 6 m.m. as the average height of the intercondyloid eminence. The maximum was 451 m.m. and the minimum 321 m.m. so that, when we compare these with the maximum and minimum of the first measurement - 446 and 316 m.m. - we see that variations in the height of this process are not great. Klaatsch (10) considers that a small intercondyloid eminence is a characteristic feature of the Orang-Aurignac type of tibia. The average size of the process in 20 European bones was 5.1 m.m.

When the measurements were made from the mid-point of the articular margin of the medial condyle to the tip of the medial malleolus, the average length was/

was found to be 377 m.m. It has been noted that this is the best measurement for comparison with the living bone.

An asymmetry between the lengths of the two tibiae has been noticed by Derry (07), Ernest Warren, as quoted by Derry, and Rudolf Martin (14). Warren found that in males the left bone is the longer in 61.4%, in females in 62%. Martin gives the following figures:-

Right tibia longer	43% Male	32% Female.
Left tibia longer	25% "	54% "
Both tibiae equal	29% "	14% "

There evidently is an error of 3% in one of the figures for the male as the total only comes to 97. In any case there is a marked discrepancy between the figures of Warren and those of Martin.

In the present series the results were, in 93 pairs of bones:-

Right tibia longer	49.4%
Left tibia longer	43%
Both tibiae equal	7.6%

These results therefore approximate more to Martin's figures than to those of Warren.

Martin thinks that where the left tibia is shorter than the right there is a compensation in the length of the femora so that the left lower extremity is/

is nearly always longer than the right.

When the length is taken, as in No.2, from the centre of the articular surface of the medial condyle to the base of the medial malleolus, we get an average of 363.2 m.m. If we subtract this from 1b - i.e. 377 - we get an average of 13.8 m.m. representing, for all practical purposes, the length of the medial malleolus. In 118 Scottish tibiae, which were measured by Mr Alec. Turner of the University Anatomy Department, the average length of the malleolus was 7.6 m.m. The malleolus in the cast of the Spy tibia in the University Anatomical Museum was 19 m.m. Klaatsch makes use of the greater length of the malleolus in the Spy-Gorilla type of tibia as one of distinguishing features from the Aurignacensis-Orang group to which he believes the Australian tibia approximates.

Relation of Thickness of Body to Length.

This relationship is indicated by the Index.

$$\frac{\text{Smallest circumference of diaphysis (10b) X 100}}{\text{Greatest length (1)}}$$

The average index for the Australian tibia was 18; the maximum was 24.9 and the minimum 7.5.

In the Swiss this index is 20.5, in Parisians 20.1 in the male and 20.2 in the female, in New Californians/

Californians 20.4 in the male and 19.6 in the female, in Mongols 21.3, and in Negroes 19.8. In Homo Neandertal it is 24 and in Spy 26.2. It will be seen that the Australian index is lower than that of any race for which the index has been calculated and presents a marked contrast to that of the Homo of Neandertal or Spy.

Relation of Length of Tibia to Body-height.

The tibia varies more in the relation of its length to the body-height than any of the other long bones. Topinard (85) has published tables of the proportion of the limb bones to the body-height. These show that the greatest proportionate length of the tibia is found among New Caledonians; the average of eight males is 23.8. The smallest tibia is that of a Samoyede, the proportion of which is given at 20.8 to the body-height; the difference between these extremes is 3. In females the difference is even greater. Topinard gives the proportion of the tibia in three female New Caledonians as 24.8, that of a female Aino as 19.9, showing a difference between these extremes of 4.2. Similarly, the difference between the extremes of the proportionate lengths of the femur is 2.3 in the males and 2.5 in the females. In the upper limb the difference in the proportions is relatively less; thus in males the difference in the/

the proportionate length of radius is 1.6, in females the variation is somewhat less. In regard to the humerus, the difference in males is 1.9, in females 1.4.

In the present investigation the body-height of the skeletons was not available but for purposes of comparison the figures which are given by Spencer and Gillen (99) for natives of Central Australia were utilised. In 30 individuals the average body-height was 163.2 c.m. If we compare with this figure the average length of the tibia in the present series - i.e. 280 m.m. - we get a proportion of 23.3, a proportion which is nearly as great as the highest in Topinard's tables.

Dimensions of the Upper and Lower Epiphyses.

Although very little work in connection with the dimensions of the epiphyses has been put on record, it would seem that these measurements are of the first importance. Pronounced race differences have been found to exist in those instances in which the measurements have been taken, as the following table shows:-

	Length of Tibia.	Upper Epiphysis	Lower Epiphysis.
Swiss	365 m.m.	72.7 m.m.	51.7 m.m.
Scottish	352 "	74 "	
Fuegian	338 "	71.6 "	51.2 "
Aino	339 mm Male 319 " Female	73.7 mm Male 67.4 " Female	506 mm Male 46.5 " Female
Japanese	333 mm Male 309 " Female	74.3 mm Male 66.8 " Female	50.8 mm Male 45.4 " Female
Spy	326 m.m.	82 m.m.	58 m.m.
Senoi	323 mm Male 319 " Female	64 mm Male 62.5 mm Female	43.5 mm Male 40.5 " Female.

The measurements quoted for the epiphyses refer to the breadth. Although these numbers are rather limited, a distinct racial difference is obvious. When we compare the short tibia of the Japanese with the European we see that the epiphyses of the former are not only relatively, but - in the case of the proximal epiphysis - absolutely broader. The Fuegian/

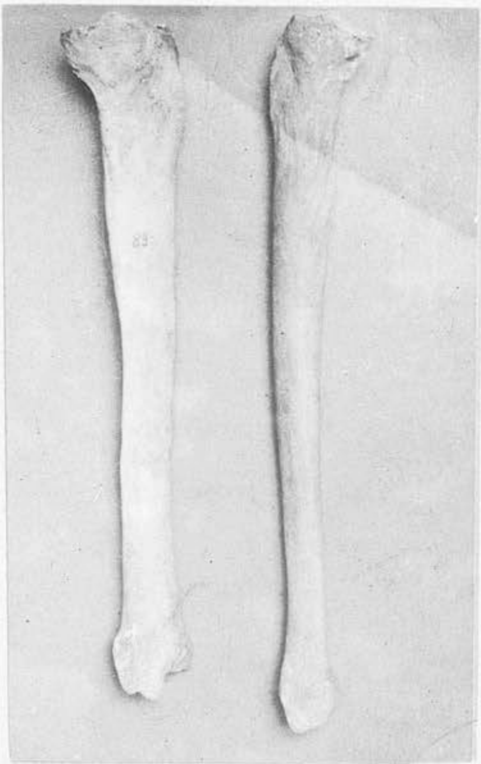


Fig. 4.

A photograph of a European and an Australian tibia from the medial side. It will be observed that the latter is more slender; the epiphyses are smaller; the outline of the malleolus is distinctly more conical.

Fuegian also possesses relatively broader epiphyses than the European. The extraordinary breadth of the epiphyses of the Spy tibia forms a marked contrast to the tibia of any other race. The figures for the present series are:-

Length of Tibia	Upper Epiphysis.	Lower Epiphysis.
380 m.m.	69 m.m.	45 m.m.

The small size of the Australian epiphyses, especially considered in relation to the great length of the bone, is therefore very striking, the breadth being less than in any other race so far measured, with the exception of the Senoi.

For the other dimensions of the epiphyses no figures were available for comparison and I give below a table comparing the results in the Australian bones with those of 40 Scottish tibiae from the Anatomy Department and of the Spy cast.

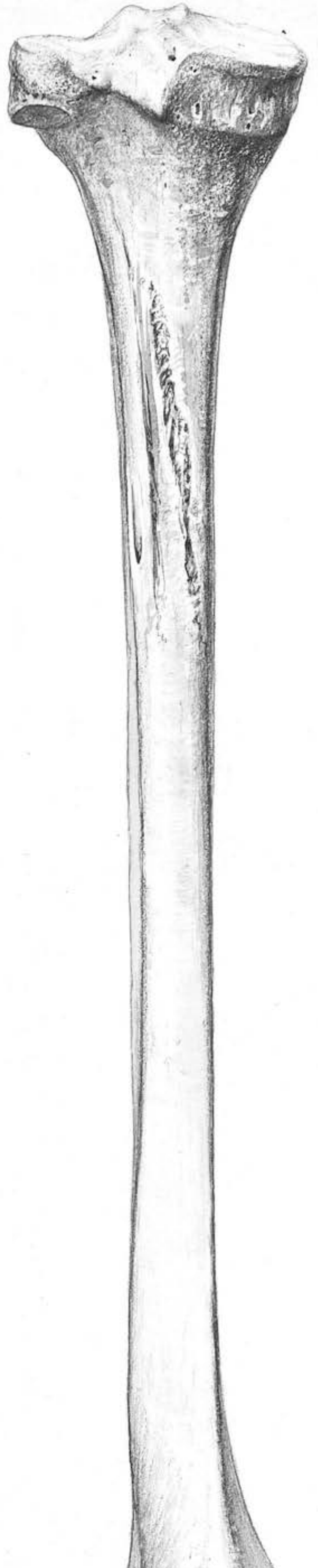
	Australian	Scottish	Spy.
Sagittal diameter at level of Tuberosity	43 m.m.	44.7	52.5
Transverse " " "	39 "	41.3	50
Sagittal diameter at Distal Epiphysis	34 "	37.9	42

For these measurements the Australian tibia holds the same relative position as for measurements of breadth.

From the measurements which have been considered so far, it is clear that the typical Australian tibia is/

Plate I.

An Australian tibia seen from behind. Note the long slender diaphysis and the relatively small and narrow epiphyses.



is a relatively long and slender bone with narrow epiphyses. The appearance of a typical tibia is well seen in Plate.I.

Relationship of Transverse to Sagittal Measurements of Diaphysis: Platycnemia.

This relationship is expressed by the Index Cnemicus which is usually calculated from the following formula:-

$$\frac{\text{Transverse diameter at level of nutrient foramen (9a)} \times 100}{\text{Sagittal diameter at same level (8a)}}$$

This is the method which has been followed by Manouvrier (87) in his classical work, by Broca (68) and Khuff (81), and by the majority of subsequent observers. The measurements at the level of the nutrient foramen have the advantage of taking into account, as a rule, the maximum amount of platycnemia, although in certain races, e.g., the Wedda, the diameters taken at the middle of the bone give the smallest index. Hrdlicka (98) objects that diameters at the level of the nutrient foramen are less satisfactory than those taken at the middle of the tibia as in/

Fig. 6.

A comparison between the Australian and the European tibia from the anterior aspect. Again the striking difference in the conformation of the two bones is apparent, the narrow epiphyses and the slender diaphysis of the Australian bone being very characteristic.

in 60% of cases the sagittal measurement in the former method is influenced by the development of the linea poplitea and also by the variable position of the nutrient foramen. Arthur Thomson (89) had previously noticed the variation in the level of the nutrient foramen. In the present investigation it was found that variations in the development of the popliteal line and in the level of the nutrient foramen were so slight as to be practically negligible.

The level which is preferred by Busk (70) and Thomson is at the point where the linea poplitea cuts the medial border, usually 3 - 4 c.m. below the level of the nutrient foramen. Martin recommends the level of the mid-point as being a fixed point and free from fallacies due to variations in the development of the popliteal line.

The figures from the present examination ought to afford some indication as to which method is to be preferred. The average transverse diameter at the level of the nutrient foramen was 22 m.m., while that at the middle of the bone was 20 m.m., a diminution of 2 m.m.; but in the case of the sagittal measurement the average figure at the former level was 33 m.m. and at the latter 29 m.m., a decrease of 4 m.m. In the calculation of the index the marked diminution in the sagittal diameter at the middle will more than compensate for the slight diminution in the transverse. The/

The actual average indices calculated from all the figures were 68.7 at the middle and 65.2 at the level of the nutrient foramen. At the point where the linea poplitea cuts the medial border the figures obtained were 21 m.m. for the average transverse diameter and 31 m.m. for the sagittal diameter, giving an average index of 67.7, a considerably higher figure than that for the level of the nutrient foramen.

We may conclude then, in agreement with Manouvrier, that measurements at the level of the nutrient foramen give the best indication as to the degree of platycnemia; they have the disadvantage of being influenced by the variation in the level of the nutrient foramen and the development of the popliteal line, but we have seen that these variations do not occur to such a degree as to be of any practical consequence.

Those at the middle of the tibia are less liable to variation but fail to indicate the true degree of flattening of the bone. Measurements at the point where the popliteal line cuts the medial border are probably liable to a certain amount of variation in level and fail also to indicate the maximum amount of platycnemia.

In/

In the present article the index calculated from the diameters at the nutrient foramen will be employed. We may note that the index will be lowered either by a diminution in the transverse diameter or an increase in the sagittal. The average cnemic index in the modern European tibia is about 70. Such a tibia on transverse section presents an outline which is practically an equilateral triangle. When the index falls below this level the transverse diameter becomes relatively diminished and the cross section begins to assume the outline of a scalene or an isosceles triangle. When the index falls below 55 the transverse flattening of the bone is very marked. Khuff adopted the following classification:-

Index below 64.9	-	platycnemic
" between 65 and 69.9	-	mesocnemic
" over 70	-	eurycnemic.

Manouvrier and Verneau adopted a somewhat different classification:-

Index below 54.9	-	hyperplatycnemic.
" between 55 and 62.9	-	platycnemic
" " 63 " 69.9	-	mesocnemic
" over 70	-	eurycnemic.

The occurrence of platycnemia or flattening of the tibial shaft has attracted much interest and has been described at length by various authors. It was first/.

first recognised by Busk in 1863 in tibiae from the caves of Gibraltar. P. Broca described it very fully in 1868 in the skeletons of Eyzies and applied to it the name of platycnemia. In his description* Broca did not suggest an explanation for the occurrence of this feature, but in a discussion at a later date he expressed the opinion that it might be due to a feeble development of the calf muscles with relatively powerful extensors, since the triangular form of tibia is especially common in those races who have well-developed calf muscles. After the work of Broca the condition was described by Wyman (75) in the bones of prehistoric races of North America. Issel (78) mentioned it in connection with the tibia of the troglodytes of Liguria and was able to deduce from the muscular impressions on the bones, especially of those of gastrocnemius, soleus, popliteus, and tibialis anterior, that this race were active on their feet and in the habit of traversing uneven country. Although his conclusions were justified, they did not constitute an explanation of the cause of platycnemia since the muscular attachments may be quite as strongly marked in the typical triangular tibia. Hartmann attributed it to excessive muscular exercise in a special direction but did not attempt to define the individual muscles involved. Virchow (80) arrived at much the same conclusions as Issel, considering/

considering the change to be due to abnormal muscular development. He showed that platycnemia was less marked in the bones of Negritos than in fossil bones and ascribed this fact to a feebler development of the leg muscles. Danielli and Khuff (81) described the condition. Schaaffhausen attempted a more detailed explanation than any of his predecessors. He stated that the erect attitude, which is less developed in savage races and of which the anthropoids are incapable, is dependent on the predominance of the extensor muscles over the flexors. He showed that in monkeys the flexor digitorum longus is excessively active and ascribed the condition of platycnemia to hypertrophy of this muscle. He believed that the same hypertrophy existed in savage races. Manouvrier (88) has shown that the tibia of savage races does not exhibit any sign of hypertrophy of the flexor digitorum longus and that of all the leg muscles this is the one which gains least in platycnemia. Nadaillac (83) made, in the case of prehistoric Americans, two suggestions as to the cause of platycnemia, the former of which coincides to a certain extent with the theory evolved later by Manouvrier; he thought that it might be due to the excessive muscular activity to which these races were condemned in hunting owing to the absence of domestic animals, or to a habitual use of the foot for the act of prehension./

prehension. There are no facts in support of the latter theory. Pruner-Bey (86) believed that platycnemia was the result of rickets. Although this change may occur to a marked degree in rickety tibiae and especially in the tibiae of certain ill-fed and badly-nourished Australian aboriginal tribes (c.f. the description of the "boomerang-tibia" by Messrs Spencer and Gillen in The Natives of Central Australia), it is impossible to accept this theory in view of the frequent occurrence of the condition in races in the most favourable environment. Hovelacque and Hervé (87) returned to the theory of Broca, that the condition is due to a relative weakness of the calf muscles, especially of the tibialis posterior, so that the more powerful extensor muscles tend to compress the tibia and flatten it transversely.

The most important work on platycnemia has been carried out by Manouvrier. He took up the exactly opposite view to Broca, Hovelacque and Hervé. He showed, in the first place, that negroes, in whom the calf muscles are feebly developed and who ought therefore to be platycnemic, are nearly always eurycnemic. He pointed out also that in the bones examined by Broca the linea aspera of the femur was rough and extremely well developed, indicating the existence of powerful muscles on the back of the thigh. Since the muscles of the calf are closely related in their movements/

movements to those of the back of the thigh they ought to be developed to an equal degree. He proceeded to examine a large number of platycnemic tibiae from a neolithic graveyard in Crécy and from the Canaries. He was then able to arrive at the following conclusions:-

1. In a platycnemic race, platycnemia does not exist in infants. It only commences to appear during the later period of adolescence.

2. Platycnemia is less frequent and less pronounced in the female sex than in the male.

3. Platycnemia is less frequent and less pronounced, generally speaking, in men of large stature than in those of medium or small stature.

4. In the same population, one finds tibiae very platycnemic and tibiae perfectly triangular.

He was able to conclude also that platycnemia is not a race character but is essentially an individual variation dependent upon anatomical and physiological conditions producing their effect towards the end of adolescence and operating upon individuals of any race, sex, or height, but met with more often in certain populations, in the male sex, and in individuals of average or small stature and especially in those whose tibia was narrow relatively to its length.

He/

He was then able to refute the theories of those authors who ascribed platycnemia to a relative weakness of the posterior muscles of the calf and believed that the change consisted of a simple transverse narrowing of the tibia by the lateral compression of the anterior muscles and the disappearance of part of the posterior surface. He showed that, in the same population, tibiae which are platycnemic are equal in weight and length to those which are triangular and that the antero-posterior diameter is increased at the expense of the transverse. From the measurements of his Crecy tibiae he gives the following table:-

The 14 most flattened tibiae (Indices below 60)

Transverse diameter	22.5 m.m.	Total 62.5 m.m.
Antero posterior "	40 m.m.	

The 15 least flattened tibiae (Indices above 64.9.)

Transverse diameter	25.9 m.m.	Total 63.7 m.m.
Antero-posterior "	37.7 m.m.	

Here the platycnemic tibia has gained in the antero-posterior direction almost as much as it has lost in the transverse. He ascertained, besides, that the antero-posterior elongation affects mainly the part of the bone which lies posterior to the attachment of the interosseous membrane. (See ~~Fig. 1~~ Plate II.) He proceeded to examine the impressions produced on the bone by the attachments of the muscles and found that in/

in platycnemic bones these were not only not diminished but were actually more distinct. He concluded that in platycnemic bones -

1. The linea poplitea to which are attached the popliteus, soleus, tibialis posterior, and flexor digitorum longus, preserves its length and roughness. In addition, in order to preserve its length in spite of the diminution in breadth of the posterior surface of the tibia, it becomes more oblique and bent in such a way as to become almost parallel, in certain cases, to the diaphysis. This would obviously not be so in the case of a line where the need for muscular attachment to it was diminished. This appearance of the popliteal line is seen in ~~Fig.~~ Plate I

2. The surface of origin of the tibialis anterior presents, on the whole, neither an increase nor a diminution in platycnemic tibiae.

3. The surface for the tibialis posterior, far from becoming reduced in size as the result of the conversion of the posterior surface into what is more or less a border acquires a remarkable breadth and length in platycnemic tibiae. By measurements at the level of the nutrient foramen he showed that the breadth of the origin of tibialis posterior was much greater in relation to that of the tibialis anterior than in the triangular bone.

It will be necessary to go into his explanation of/

of this change in some detail. Fig. 7, which is taken from Manouvrier and which represents transverse sections at the level of the nutrient foramen, shows

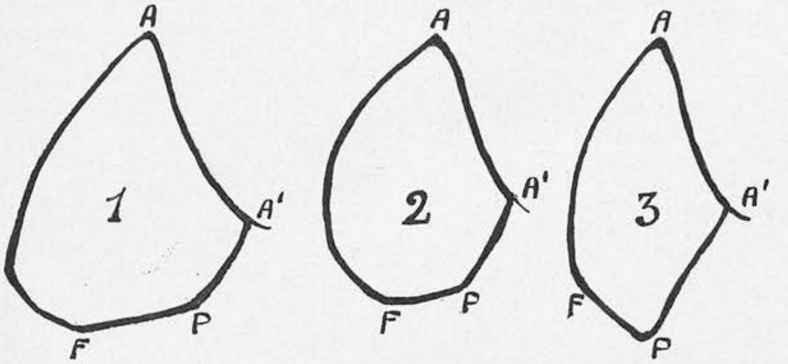


Fig. 7. A. Anterior border. A.A[1]. Surface of origin of Tibialis anterior. A[1]P. Origin of Tibialis posterior. P.F. Origin of Flexor digitorum longus

the passage of the ordinary form of tibia (1) to the slightly platycnemic form (2), then to extreme platycnemia (3) of the most common variety.

The surface of origin of the tibialis posterior is not only enlarged in platycnemia, it is, at the same time, much better marked than in ordinary tibiae. It becomes often slightly concave instead of being convex as in the latter and reveals thus an analogous appearance to the surface of origin of the tibialis anterior. This is a significant fact because muscles which are attached directly by fleshy fibres to osseous surfaces tend, by their growth and their extension, to render these surfaces concave. In/

In this way are excavated the temporal fossa, the iliac fossa, etc. The reason for this excavation is twofold.

In the first place, a flat surface of origin is increased by becoming hollowed out (AOB> AB. Fig. 8).

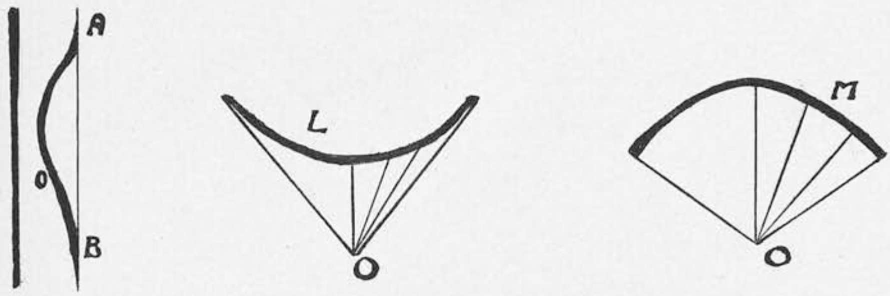


Fig. 8.

In the second place, where a muscle arises from a convex surface L, the most excentric fibres have an oblique surface of origin in relation to the direction of their action, whereas a concave surface M furnishes to all the fibres a surface of origin perpendicular to their direction.

This being so, it is easy to relate the increase of the tibialis posterior to the elongation of the posterior part of the tibia at the expense of the transverse diameter of the bone. This is demonstrated in Fig. 9. The dark line represents in section/

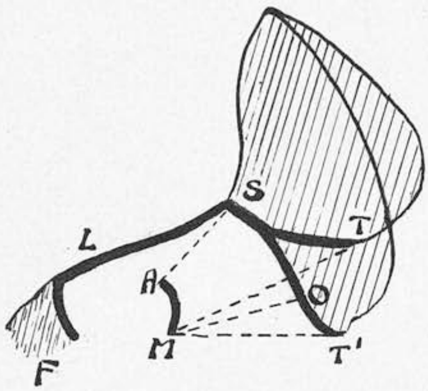


Fig. 9.

section the surface of origin of the tibialis posterior on the medial surface of the fibula, the posterior surface of the interosseous membrane, and on the postero-external surface of the tibia. The curved line AM indicates in section the tendinous portion of the tibialis posterior on which all the muscular fibres converge. The line ST represents the area of origin in an ordinary tibia, and the line ST^1 is the same line straightened out and elongated in a platycnemic tibia. By merely inspecting this figure it is at once seen what a great advantage results for the tibialis posterior from this straightening out and elongation, since, on the one hand, the tibial attachment of the muscular fibres, even in/

in those nearest to the point T, has become perpendicular to their direction and since, on the other hand, the transverse section of the tibial portion of the muscle, which was AMST in the case of the triangular tibia, has become $AMST^1$ in the case of the platycnemic tibia. The increase in this transverse section would exist even by the sole fact of the straightening out of the line ST, which has become So, without the elongation oT^1.

This figure, which, although it is diagrammatic, represents real facts, shows that the flattening of the tibia seems to have for its only purpose the elongation and the straightening out or "redressement" of the postero-external aspect of this bone, i.e. the surface of origin of the tibialis posterior, a muscle which is always somewhat postero-external even in the most triangular tibiae. It is therefore reasonable to believe that the morphological modification of the bone is an adaptation required by the needs of the muscle which benefits by it. The tibialis posterior pulls toward it, in a way, the posterior surface of the tibia and this antero-posterior elongation occurs at the expense of the thickness of the bone, so that the internal surface is approximated to the external as is shown in Fig. 9.

In Fig.10 are illustrated two rare forms of platycnemia. In No.1 the surface for the tibialis posterior/

posterior lies in exactly the same plane as that for

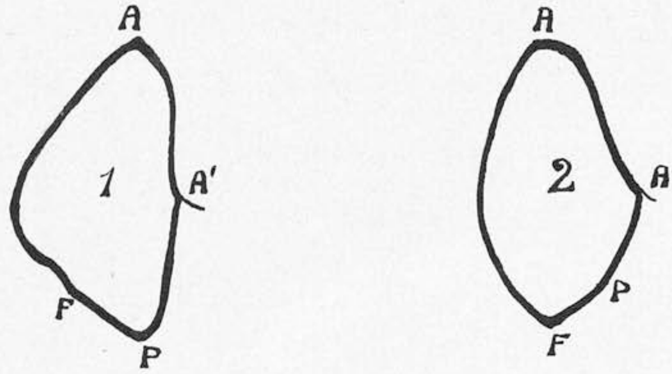


Fig.10. Lettering as in Fig 7.

the tibialis anterior; this variety is extremely rare. In No.2 the surface of origin for the flexor digitorum longus also lies on the lateral aspect of the bone. The posterior surface of this bone no longer exists and has been converted into a more or less well-defined border. The anterior border is somewhat rounded off. The special interest of this form, although it is rare, lies in the fact that it resembles very closely the variety of platycnemia which is met with in the gorilla. It is more common than the preceding variety, Manouvrier having met with it in about 40 cases, and it is not confined to any special race, being found in natives of Paris, Canary Islands, Venezuela, California, New Hebrides, etc. This type corresponds always to a marked platycnemia,/

platycnemia, the average for the cases of Manouvrier being 57 - 58, varying between 31 and 64.

Manouvrier suggested also another explanation for platycnemia, - that it might be a direct adaptation of the bone in resistance to forces tending to bend it in an antero-posterior direction. He showed that, when the knee is flexed, especially in running and leaping, in view of the retroversion or retroflexion of the proximal extremity which is usually well-marked in platycnemic races, the tibia is subjected to great force tending to bend it sagittally. From a mechanical point of view a bone with its greatest diameter in the direction of the plane of flexion, as in platycnemic tibiae, would afford the greatest resistance to the bending force.

He raises three objections to this second theory. In the first place, the shape of the tibia, in man and in other mammals, is always intimately related to the volume and disposition of the muscles attached to it and the platycnemic bone forms no exception to this law. Secondly, if the flattening of the tibia resulted directly from forces tending to bend it, the platycnemic tibia would not be flattened only in its superior portion since the centre of curvature of tibiae which have not been able to resist flexion is situated about the middle of the bone,/

Fig. 11.

A somewhat mutilated specimen which shows very well the ridge on the posterior surface of the bone termed by Manouvrier the "posterior tibial crest". It will be noted that retroversion is not marked. It is impossible to explain such an appearance as this on any other theory than a hypertrophy of the tibialis posterior muscle.

bone, i.e. at a level at which platycnemic tibiae are commencing to return to the triangular shape, which is less favourable to resistance; while the maximum amount of flattening occurs in the upper third of the bone, that portion which is precisely the strongest. In the third place, we find in many bones a vertical crest produced by the extension of the tibialis posterior muscle. If it were not for the occurrence of this ridge we might explain the "redressement" of the posterior surface as a result of the flattening of the bone. The appearance of this crest shows that the tibialis posterior is the essential agent in the flattening since, the "redressement" of its tibial surface of origin not being sufficient for it in spite of the extension of surface which results from the alteration in direction, the muscle still determines the formation of a supplementary ridge.

He maintains that the first is the only plausible theory.

The hypertrophy of the tibialis posterior he considers to be due in man, not to excessive action of the muscle in the direction of flexion and adduction of the foot, but to its indirect action. This action comes into play when the foot is fixed to the ground and has the result of immobilising the tibia so that it may be able to support the weight of the body/

body on its superior extremity. This action will be especially important when the knee is somewhat flexed as in running or leaping. The resulting platycnemia would therefore be more marked in races who lived in rocky, uneven country and who followed the chase. This would explain the fact that it is absent in infants and relatively rare and less marked in women. It would be more marked in individuals of average or small stature since these are better adapted to the pursuit of hunting.

In anthropoids, the platycnemia is the result of the direct action of the muscle. The orang is exceptional in having a eurycnemic tibia; this condition Manouvrier explains by the indolent habits of the animal. The degree of platycnemia in the anthropoids is never so great as in man, and Manouvrier emphasises the fact that the platycnemia of man is not the remains of a simian feature but is the result of a function essentially human produced by special conditions of life.

The work of H. Vallois on the tibia of anthropoids and the lesser monkeys has served to strengthen very considerably the theory of Manouvrier. He studied the relative volume of the muscles attached to the bone in transverse sections through the calf at the level of the nutrient foramen. In the Chimpanzee which gives a cnemic index of 61.9 he found/

found that the tibialis posterior took origin from a markedly elongated postero-external surface. The tibialis anterior was relatively small. The appearance of the section is seen in Fig. 12.

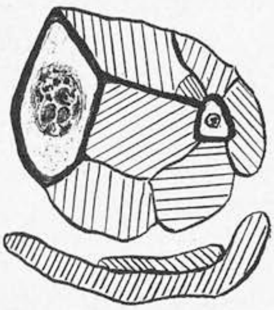


Fig. 12.

He was unable to procure a specimen of the gorilla but since the tibia of this animal has the same form and index as that of the chimpanzee it is most likely that the appearance of the transverse section of the calf would have been similar. In the Orang which is decidedly eurycnemic, with an index of 76.1, he found that the surface of origin of the tibialis posterior was small and looked almost directly backwards. The tibialis anterior was more voluminous than the posterior, the ratio between the two being practically the same as in modern European man.

In the Gibbon he discovered a very interesting feature./

feature The index in this animal is 60 and a marked hypertrophy of the tibialis posterior, as in the Chimpanzee, would be expected. He found, however, only moderate hypertrophy of the tibialis posterior but considerable hypertrophy also of the tibialis anterior, so that the two muscles presented much the same ratio as in man, although they were both enlarged in comparison with the other muscles of the leg. In other monkeys, especially in leapers, he found that there was marked hypertrophy of the tibialis anterior alone, the posterior not being increased and in some species being even considerably diminished in size. In such cases of hypertrophy of the tibialis anterior alone he found that marked elongation of the bone in the sagittal direction took place as the result of this hypertrophy. The consequence of this change is naturally a lowering of the cnemic index. This condition does not occur in man and is to be distinguished from platycnemia which is due to an elongation of that part of the tibia which lies posterior to the attachment of the interosseous membrane. In the Gibbon a mixed condition exists due partly to hypertrophy of the tibialis posterior and partly to hypertrophy of the tibialis anterior.

The special value of the work of Vallois lies in/

in the fact that it shows clearly that the amount of antero-posterior elongation of the tibia is in direct relationship to the volume of the two tibiales muscles and Manouvrier has already shown that in platycnemic bones the volume of the tibialis anterior is unchanged. There remains only the possibility of an increase in the volume of the tibialis posterior.

The theory of Manouvrier has been criticised by Hirsch (95) and Klaatoch (00) and is affected, to a certain extent, by the work of Havelock Charles(93) and Macrae Aitken (05).

Hirsch, following on the lines of the mathematical work of Wolff (70) in connection with cancellous tissue, endeavoured to explain the occurrence of platycnemia as the result of purely mechanical influences derived from the function of the bone. We have seen that this view had already been discussed by Manouvrier. Hirsch denied absolutely the influence of muscles on the external shape of the bone and believed that the form depends entirely on the pressure exercised on the articular surfaces and the traction applied to the bone through the muscular attachments. He accounted for the occurrence of platycnemia as an adaptation in the shape of the bone in order to resist forces tending to bend it in a sagittal direction. This force would manifest itself especially in running and jumping. He believed that/

that in those savage races in which platycnemia occurred to an extreme degree the change was largely due to crouching attitudes which they adopted for prolonged periods at their sacred dances. It is not necessary to consider the work of Hirsch in detail nor to repeat the objections of Manouvrier to such a theory. The work of Fick (58), Guerin, Marey, Anthony (03), Regnault (01), Papillault (01)- and others has shown conclusively that the essential factor in the shape of any bone is the adaptive action of muscles. Another powerful objection to the theory of Hirsch is that it fails to take into account the influences of heredity. Vallois shows also that it does not explain the co-existence of platycnemic tibiae with platymeric femora; the same force which elongates the tibia antero-posteriorly flattens the femur in the same direction.

Klaatsch raised several objections to Manouvrier's theory. He stated, in the first place, that the most common change in platycnemia is not an elongation of the bone but merely a rounding of the posterior surface. He objects also that it does not explain the occurrence of that somewhat rare form of platycnemia in which the surfaces of origin of both the flexor digitorum longus and the tibialis posterior are directed laterally and which resembles closely the/

the condition found in the gorilla. Manouvrier explains this change by supposing that in such cases a very close relationship exists between the origins of the tibialis posterior and the flexor digitorum longus so that the surface of origin of the latter muscle is, as it were, drawn round to the lateral aspect of the tibia with that of the tibialis posterior. Klaatsch maintains also that the theory of Manouvrier does not explain the absence of platycnemia in certain of the Spy tibiae. From some of the specimens he obtained an index of 70.7. In this race the conditions alleged by Manouvrier to produce platycnemia in other races must have been existent but no platycnemia has resulted. Manouvrier believes that the tibia in these cases has escaped platycnemia because of its remarkable shortness and thickness so that the tibialis posterior already had a large surface of origin and no further increase in the sagittal diameter was necessary to provide further space for hypertrophy of this muscle.

The most important criticism of Klaatsch, therefore, is that he maintains that the antero-posterior diameter of the tibia is not increased in platycnemia and the lowering of the index must then be due to a diminution in the transverse diameter of the bone. I shall discuss this point in relation to the series of Australian tibiae presently.

D. E. Derry (07) raises the same objection as Klaatsch, holding that the principal change in platycnemia is a diminution in the transverse diameter. He founded his conclusions on the examination of between four and five hundred predynastic Egyptian tibiae but, unfortunately, he gives almost no measurements, apparently having only inspected the bones, and his results are therefore of small value.

Havelock Charles raised what at first sight appears a somewhat formidable objection to the theory of Manouvrier. He showed that the condition of platycnemia is common in natives of the Punjab who are dwellers on a plain as level as Holland and do not engage in hunting. But he was able to reconcile this form also to the theory that the essential cause of the modification is a hypertrophy of the tibialis posterior. He attributed it to the prevalence of the attitude of squatting in this race. He showed that in this posture the weight is transmitted from the talus to the inferior calcaneo-navicular ligament, which thus bears a relatively greater strain than in the European, and therefore the tibialis posterior will have more to support, as it will also have more work to perform when the individual arises from the squatting position. An excess in development will naturally be the result.

Macrae/

Macrae Aitken in an incomplete but very interesting article showed that bones possessing a comparatively low cnemic index were of common occurrence in modern races. Such bones possessed certain other characteristics and were classified by him as belonging to the "Oriental" type. The other features found in these bones were backward displacement of the upper extremity, convexity of the articular surface of the lateral condyle, and articular facets on the anterior border of the lower epiphysis for the talus. He examined 55 tibiae from the dissecting rooms of the New School, Edinburgh, and found that 32% of these were of the Oriental type. These bones were shorter and slighter in build than the typical European and the impressions for the attachment of muscles and the groove for the tendon of the tibialis posterior were less distinct. He found that platycnemia and backward displacement of the upper end occurred together. 29 bones out of the 55 showed more or less backward displacement of the upper end and their average index was 67.1. He considers that the backward displacement of the upper end of the tibia must mean that the weight of the body is transmitted from the condyles of the femur obliquely forwards to the body of the tibia and that nature meets this strain by increased growth in the antero-posterior direction. In other words, he employs the mechanical theory to account/

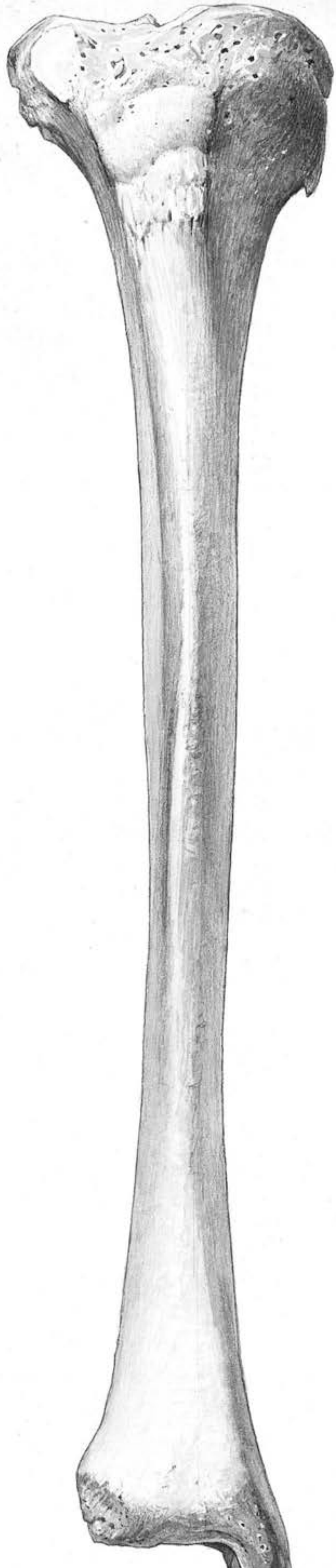
account for these cases of platycnemia which occur in modern Europeans. He accounts for the backward displacement of the head in such cases as a persistence of the retroversion which is present in the foetus. Hypertrophy of the tibialis posterior did not exist in these bones, this being indicated by the faintness of the muscular impressions. In a*ddition, in the modern European individual there is no exciting factor for such hypertrophy in existence, as occurs in savage races, e.g. hunting, the attitude of squatting.

How far does the examination of the present series of bones support Manouvrier's theory? The most serious objections are those of Klaatsch, who denies that the sagittal diameter is increased to any great extent, asserting that the principal change in platycnemia is a diminution in the transverse diameter of the bone, and of Macrae Aitken, who apparently demonstrates the occurrence of a certain degree of platycnemia in the absence of any hypertrophy of the tibialis posterior. Are there two possibilities, the theory of Manouvrier explaining the majority of cases occurring in savage races but the mechanical theory being necessary to explain those cases occurring in Europeans?

Considering first the criticisms of Klaatsch and Derry, it is an easy matter to show that the principal/

Plate II.

A platycnemic tibia illustrating the great increase in the sagittal diameter in this condition. The cnemic index of this bone was 51.9. The transverse diameter was 21 m.m., which is only 1 m.m. below the average for the whole series, showing conclusively that the main alteration is an increase in the sagittal diameter. Note also the facet on the anterior aspect of the lateral condyle and the position of the crista interossea.

principal change in platycnemia is not a simple transverse narrowing of the bone. Manouvrier himself has shown that the weight of platycnemic bones is equal to that of eurycnemic, therefore if they lose in their transverse diameter they must also gain in some other direction. A glance at the table of measurements at the end of this article will show that in many platycnemic bones the transverse diameter is actually above the average of 22 m.m. so that the factor which causes a lowering of the cnemic index in such bones is the increase in the sagittal diameter alone. In order to show the relationships between the sagittal and transverse diameters in platycnemic and eurycnemic bones I have made out the table which is given below from bones selected from the present series. It will be seen that in each two bones compared the sum of the sagittal and transverse diameters is exactly equal.

Platycnemic bone (Index 62.9-69.9)		Eurycnemic bone (I 70 & upwards)		Total in each case.
Sagittal.	Transverse.	Sagittal.	Transverse	
3 c.m.	1.8 c.m.	2.8 c.m.	2 c.m.	4.8
3.6	2.1	3.3	2.4	5.7
3.3	1.8	2.95	2.15	5.1
3.1	1.9	2.9	2.1	5
3.6	2.1	3.3	2.4	5.7
2.9	1.7	2.7	1.9	4.6
3.65	2.2	3.4	2.45	5.85

3.2 c.m.	1.8 c.m.	2.8 c.m.	2.2 c.m.	5
3.6	2.1	3.3	2.4	5.7
3.7	2.2	3.4	2.5	5.9
3.5	2.1	3.2	2.4	5.6
3.7	2.3	3.5	2.5	6.0
40.85	24.1	37.55	27.4	64.95

From the sum of these figures it is evident that in platycnemic bones the alteration in the two diameters is nearly equal - what is lost in the transverse direction is made up in the sagittal. As regards the cause of the elongation in the antero-posterior direction there could be no doubt that, in the great majority of cases in the present series, it was an increased activity of the tibialis posterior muscle. When contrasted with a European bone, the area for the attachment of this muscle showed a striking increase both in length and in breadth. To verify this appearance I have measured the breadth of the origin of tilialis anterior and posterior at the level of the nutrient foramen in the platycnemic bones of the series, and, for purposes of contrast, in 12 eurycnemic European tibiae. In the platycnemic bones the average diameter of the tibialis anterior was 22.3 m.m. and of the posterior 18.3 m.m., a diminution of only 4 m.m.; in 12 European tibiae, which were/

were selected at random from those with indices of 70 and over, the measurements were 26 m.m. and 14.7 m.m., which shows a decrease in the breadth of the posterior of 11.3 m.m. These figures show very definitely the increase in area of the origin of the tibialis posterior. The length of the attachment of this muscle also showed a marked increase in the great majority of platycnemic bones, as is shown in Plates II and IV , but it is somewhat difficult to estimate exactly the lower limit of the attachment so that measurements of length have not been made.

We may take it, then,that the theory of Manouvrier as to the cause of platycnemia is correct regarding the condition as it occurs in savage races. There still remain those sporadic cases which occur among modern Europeans, mentioned especially by Manouvrier and Macrae Aitken; at first sight it would seem that in those individuals there is no possibility of a hyperactivity of the tibialis posterior such as is produced by hunting and running and explains the platycnemia of savage races. In order to estimate the frequency of this change an examination was made of 118 tibiae from the University Anatomy Department. In these bones there were 14 examples of platycnemia proper with indices between 62.9 and 55 and 43 cases of mesocnemia with indices between 63 and 69.9; the remaining/

remaining 61 bones were eurycnemic. The lowest index met with was 56.7. To show that the sagittal and transverse diameters are altered in very much the same way in European and in Australian platycnemia, I have made out the following table from 9 bones of each type, the sum of the two diameters being the same in each pair of bones.

European.		Australian.		Total.
Sagittal.	Transverse.	Sagittal	Transverse.	
4.0 c.m.	2.5 c.m.	4.05 c.m.	2.45 c.m.	5.5
3.5	2.1	3.5	2.1	5.6
3.7	2.1	3.6	2.2	5.8
3.4	2.1	3.4	2.1	5.5
3.4	2.1	3.5	2.0	5.5
3.5	2.1	3.5	2.1	5.6
3.7	2.3	3.7	2.3	6.0
3.6	2.1	3.3	2.4	5.7
3.6	2.2	3.6	2.2	5.8
32.4	19.6	32.15	19.85	

Macrae Aitken stated that such cases of platycnemia in Europeans were associated with backward displacement of the upper extremity and believed that the increase in the sagittal diameter was a compensatory change developed to meet the increased strain in the antero-posterior direction. He found that these bones/

bones were slighter in build than the typical European and presented poorly-marked impressions for the attachment of muscles. He believed that the cause of the platycnemia was purely mechanical. An examination of the 14 platycnemic bones in the series of 118 failed to support this theory. In only 4 of the platycnemic tibiae was retroversion or retroflexion present so that in the majority of cases this causal factor was absent. The muscular attachments, and that of the tibialis posterior in particular, were, as a rule, well-marked in the platycnemic tibiae. The impression for the tibialis posterior showed the same increase in length and breadth as was described by Manouvrier in his typical cases of platycnemia. The average breadth of the impression at the level of the nutrient foramen was 18 m.m., that of the tibialis anterior being 24 m.m., a difference of only 6 m.m., whereas in 12 eurycnemic bones the difference was 11.3 m.m. The relationship between the relative dimensions of the muscular origins is therefore much the same as in the platycnemic Australian bones.

As regards the physiology of this form of platycnemia further investigation would be required and a knowledge of the habits of the individual from whom the tibiae were derived, but one can readily imagine that in certain occupations, such as that of a hill-shepherd/

shepherd or a postman, a hypertrophied tibialis posterior might very well exist. Arbuthnot Lane (88), in particular, has shown how very much the skeleton may be modified by occupation and indeed, the work of Lane, showing, as it does, how increased strain on a muscle may produce marked alteration on its osseous origin, is strongly in support of the theory of Manouvrier.

As mentioned above, Aitken differentiates an "Oriental" type of tibia, a bone showing the association of platycnemia with convexity of the articular surface of the lateral condyle, backward displacement of the upper extremity, and articular facets on the anterior border of the distal extremity for the talus. An examination of the present European series showed that, although these additional features were somewhat more common in platycnemic than in non-platycnemic bones, they were so frequently absent in platycnemia that there seems no sufficient ground for classifying the former bones as "Oriental". In the platycnemic bones, convexity of the condyle occurred in 28.5%, in non-platycnemic bones in 7.6% of cases; well-marked backward displacement of the upper extremity - including both retroversion and retroflexion - was present in 28.5% of the former and in 6.8% of the latter; while the facets for the talus appeared in only/

only 14.25% of platycnemic and in 14.4% of non-platycnemic bones.

We may conclude that the theory of Manouvrier is the correct explanation of practically all casee of platycnemia. The increase in the sagittal diameter of the tibia will render it more resistant to forces tending to bend it but the essential factor in the production of that increase is hypertrophy of the tibialis posterior.

ETHNOGRAPHICAL POSITION OF THE AUSTRALIAN TIBIA AS REGARDS PLATYCNEMIA.

From the examination of a very large number of tibiae obtained from very various sources, Manouvrier arrived at the following conclusions:-

1. Platycnemia is met with in divers degrees and with a variable frequency in all races which have been studied.

2. It is, generally speaking, much more accentuated and frequent in ancient peoples than in modern, in savage than in civilised nations. It is especially rare in modern Europeans.

3. Certain populations are particularly platycnemic, e.g. the prehistoric races of France in general, the ancient Guanchos, Indians of High California, and Negritoes of the Phillipines.

In the Australian bones the average cnemic index was/

was 65.2. The highest index obtained was 86.2 and the lowest 50. Of the 236 tibiae 7 were hyperplatycnemic, 74 were platycnemic, 114 were mesocnemic, and only 41 were eurycnemic according to the grouping of Manouvrier. The following table gives the average cnemic index for the principal races in which it has been ascertained.

		Author.
Aino	59.3	Koganei
Veddah	60.5	Sarasin
Anau	61.5	Mollison
Californian Indian	62.5	Bello
Neolithic of Feigneux	62.8	Topinard
Negrito	63.1	Bello
Dolman of Port Blanc	63.3	Bello
Aino	63.5	Koganei
Salado-Indian	63.5	Matthews
New Caledonian	63.7	Manouvrier
Patagonian	63.8	Bello
Negrito	64.5	Manouvrier
Cro-Magnon	64.5	Bello
Melanesian	64.7	"
Andaman Islander	64.7	Flower
Polynesian	64.8	Bello
Neolithic	65.2	"
Guancho	66.0	"
Paltacalo Indian	66.1	Rivet.

Malay	66.6	Bello
Peruvian	66.9	"
Senoi and Semang	67	Martin
Tierra del Fuegan	67	"
Altequadorian	68.3	Bello
Parisian	70	Topinard
Swiss	70.6	Martin
Scottish	70.7	Wood
Alamann of Switzerland	71.4	Schwerz
French	71.4	Bello
Swabian and Alamann	71.6	Lehman-Nitsche
Bajuvar	72.2	" "
Negro	72.3	Bello
Parisian	73	Manouvrier
Middle Ages, French	73.3	Bello
Japanese	73.7	"
"	74.1	Koganei
Lorrainese	74.1	Manouvrier
Gibraltar	59.3	Duckworth
Spy	65.8	Bello
"	70.7	Klaatsch
La Chapelle-aux-Saints	69	Boule
Homo of Neandertal	71.3	"

The Australian bones have the same index as the Neolithic specimens examined by Bello. The index is on/

on much the same level as that of most of the American types, the Malays, and the Polynesians. Arthur Thomson estimated the cnemic index in 14 Australians and found it 64.1, a somewhat lower figure than that of the present series.

In the table just given it will be seen that recent and historic Europeans, Japanese, and Negroes belong to the eurycnemic group. Most of the prehistoric European forms, however, lean more towards platycnemia than the recent ones, in which a pronounced platycnemia is only rarely observed. The Homo of Neandertal is, nevertheless, distinctly eurycnemic and for the Homo of Le Monstier Klaatsch gives an index of 87.1, a value which approaches the recent European maximum.

The Anthropoids, with the exception of the Orang are to a certain degree platycnemic as will be seen from the following table.

	Bello.		Manouvrier.
Gorilla	64.2	(56 - 69)	65.1
Chimpanze	61.9	(55 - 69)	64.7
Orang	76.1	(72 - 81)	76.9
Hylobates	61-69	(54 - 68)	63.5

The index is comparatively high in the Anthropoids and it has been mentioned that Manouvrier does not regard the platycnemia of man as a simian character since/

since it occurs to a greater degree in man than it does in the anthropoids; he does not believe that it is an inherited character derived from a common simian ancestor since, in the anthropoids, the Orang is not platycnemic. He thinks that it has been developed independently in the anthropoids and in man.

THE OUTLINE OF THE TIBIA AT THE LEVEL OF THE NUTRIENT FORAMEN.

In considering platycnemia the alteration in the outline of the bone has been discussed and the principal forms met with by Manouvrier have been described (see Figs. 7 and 8). In the typical case of platycnemia he found that the posterior surface was converted more or less into a vertical border so that the surface of origin of the tibialis posterior was directed postero-laterally and that for the flexor digitorum longus somewhat medially; a second type in which the surface of origin of the flexor digitorum longus was also directed laterally was encountered on several occasions.

Hrdlicka (99) has paid special attention to the outline of the tibia. He subdivided tibiae into six types according to the appearance of the transverse section of the bone; these types are reproduced in Fig.14. 1.The first and most common form

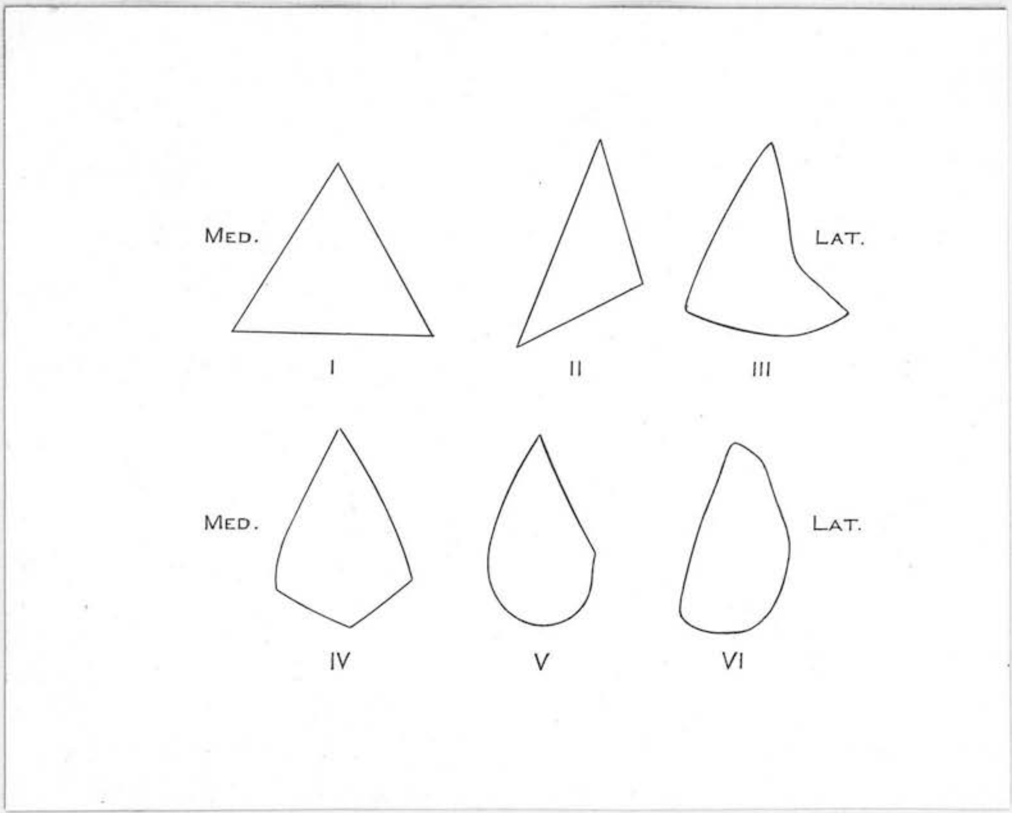


Fig. 14.

in the adult European is that of an equilateral triangle, one side of which is almost directly posterior.
2. In the second type this surface looks somewhat more outwards, so that the sides of the triangle become of unequal length and the base becomes formed by the medial surface. Naturally there are numerous intermediate varieties between these two forms.
3. The next modification is formed by the hollowing out/

out of the lateral surface in the upper two-thirds of the bone. It is most common in males and especially frequent in the tibiae of North American Indians. 4. The fourth type, which is but rarely found in females, corresponds more or less to a quadrilateral section in which the posterior surface is divided by a vertical crest into a postero-median and a postero-lateral plane. This form corresponds to Manouvrier's typical platycnemic bone. 5. In this variety the internal angle is obliterated and the total posterior half of the outline is more or less uniformly convex, a form almost entirely limited to female tibiae. 6. The last type includes all those cases in which the outline is almost oval; the lateral and posterior aspects are pronouncedly convex, while the medial surface may be relatively flat. It is rare in Europeans and North American Indians but is frequent in negroes. Hrdlicka found that it was in association with this variety that the most marked platycnemia occurred. This fact does not affect the theory of Manouvrier since it is evident that in this type also the surface of origin of the tibialis posterior may be considerably increased.

In the 236 Australian tibiae it was possible to obtain a tracing at the level of the nutrient foramen in 226 cases; the remaining bones were rejected on account of mutilations. Much the most common variety of/

of tracing was that which is described by Hrdlicka as the 4th type and which approximates in appearance to the tracing given by Manouvrier to illustrate the change in platycnemia. This variety occurred in 160 cases. Several of these outlines showed with remarkable clearness the manner in which the posterior part of the bone is pulled round towards the lateral aspect by the tibialis posterior. Fig.15 shows a reproduction of one of the tracings which bring out

Fig. 15

this change. The outline next in frequency was that resembling Hrdlicka's 5th type; the majority of the bones from which these were obtained were small and slender and probably of the female sex. Tracings with a definite approximation to the outline of an equilateral triangle only occurred in 17 instances. The 6th type of tracing, with a more or less oval outline, was well-marked in only 8 cases; the average cnemic index for these bones was 58.4, thus confirming the statement by Hrdlicka that such bones were markedly/

markedly platycnemic. Four tibiae gave an outline corresponding to Hrdlicka's 3rd type, with considerable hollowing out of the lateral surface. Manouvrier showed that such an excavation of the surface of a bone occurred in response to hypertrophy of the attached muscle, as illustrated by the temporal fossa, etc.; it seems probable, therefore, that this type is to be explained by a hypertrophy of the tibialis anterior. The 2nd type of outline described by Hrdlicka did not occur at all, nor did the type of outline described by Manouvrier as resembling that of the gorilla, where the origin of flexor digitorum longus is directed laterally. But the remaining type which Manouvrier described, in which the surface for the tibialis posterior lies in the same plane with that for the tibialis anterior while that for the flexor digitorum longus is directed backwards (see Fig. 8), occurred in 10 instances. I reproduce below examples of the six varieties of outline which occurred in the Australian bones.

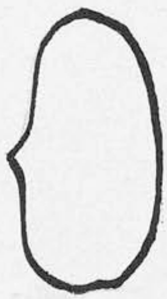
Fig. 16.

1. (Hrdlicka's 1st type)

2. (Hrdlicka's 3rd type)

3. (Hrdlicka's 4th type)

4. (Hrdlicka's 5th type)



5. (Hrdlicka's 6th type)

6. (Manouvrier's 2nd type)

In No. 5 - the most platycnemic form - it is evident that the tibialis posterior has a large surface of origin.

RETROVERSION AND RETROFLEXION.

In the European the tibia is usually straight in its whole extent. In some races it is more or less bent backwards in its upper half so that a pronounced posterior concavity results - the so-called Retroflexion. In other groups the diaphsyis is straight in its entire extent and only the upper part of the bone, including the epiphysis is slightly bent posteriorly - Retroversion. This retroversion of the head is best expressed by the angle between the tangent to the articular surface and the axis of the diaphysis. It is necessary also to consider the angle which is formed by the same tangent and the physiological axis of the bone, the physiological axis being indicated by a line between the mid-points of the upper medial articular surface and the inferior articular surface. The latter angle is termed the angle of Inclination.

The method of estimating the Inclination angle described by Martin is quite satisfactory but in measuring the angle of Retroversion considerable difficulty arises in indicating correctly the morphological axis of the diaphysis. As described under "Technique" he obtains this axis by selecting two points, the inferior of which is the mid-point of the inferior articular surface and the superior the mid-point/

mid-point c of the lateral surface a short distance below the level of the tuberosity (see diagram in "Technique".) The boundaries of the lateral surface are the crista anterior in front and the interosseous crest behind. In many bones, and especially in those which are platycnemic, the interosseous crest curves markedly forwards towards the upper end. The result of this bending is that the lateral surface is greatly narrowed in its proximal part and its mid-point at the level chosen is carried considerably further forward than it would be in a bone in which the interosseous crest was more or less vertical throughout. The axis of the diaphysis obtained in this way in platycnemic bones is inclined somewhat anteriorly and the Retroversion angle is made to appear greater than it actually is.

Manouvrier indicated the morphological axis in a different way. He placed the tibia with its medial surface in contact with a sheet of paper and held it firmly in position with the left hand. The tangent to the articular surface was obtained by applying an iron ruler about a centimetre broad to the articular surface of the medial condyle. This ruler, once placed in position, maintained itself there by its own weight and it was possible to trace, without disturbing it, a line which indicated the direction of the medial border of the articular surface. The morphological axis/

axis of the diaphysis was indicated by taking a pencil split throughout its length and applying the flat surface to each side of the bone about the level of the nutrient foramen, marking two points, m and n, at the front and the back of the bone on the same level. The lower point was taken at the tip of the medial malleolus and then, on the bone being lifted away, this latter point, O, was carried upwards about a centimetre to bring it to the level of the inferior articular surface. A line drawn from O through the mid-

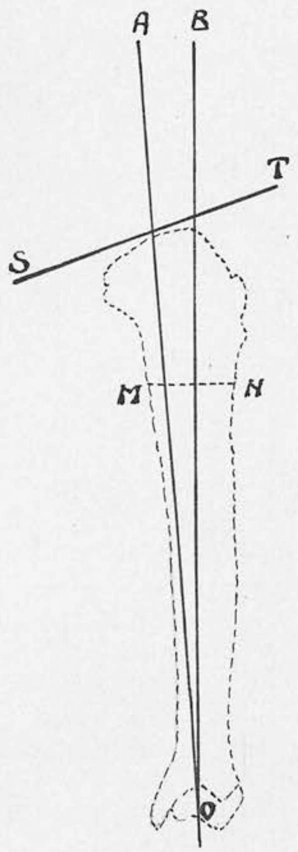


Fig.17.

mid-point of the line m n indicates the morphological axis.

This method is open to several objections. Apart from the technical difficulties of exactitude in indicating the position of the points selected, the extent of the line m n will be much affected, especially in platycnemic bones, by the varying development on the posterior surface of the median ridge which Manouvrier calls the "posterior tibial crest" and Duckworth calls a "keel or flange", which is produced by hypertrophy of the tibialis posterior. Again, when the tibia exhibits distinct retroflexion the mid-point of the line m n does not indicate the position of the morphological axis but lies posterior to it. Lastly, when the bone presents a marked degree of torsion, not only is the lower point O thrown out, but there is difficulty in maintaining the bone steady in the proper position without rolling to one side or the other.

In the present research the method of Martin has been preferred as being less liable to serious error and more convenient than Manouvrier's. When the fallacy was recognised in connection with the mid-point c of the lateral surface, an attempt was made to discover a better method of estimating this upper point. In some tibiae a definite border is found situated a little behind a forward-curving inter-

osseous/

interosseous crest and more or less in line with the general direction of the lower vertical portion of the latter. The mid-point between such a border and the crista anterior gives the line of the morphological axis very satisfactorily. But on further examination it was found that in a large number of bones with a forward-curving interosseous crest the above-mentioned border was ill-defined or absent. It was thought best, therefore, to adhere literally to the method of Martin and to employ the interosseous crest as the posterior limit of the lateral surface, this being a definite landmark which is always present. In estimating transverse diameters also, it is better to take the interosseous crest as the lateral border than any inconstant ill-defined border such as that mentioned above.

I am now convinced that the best means of indicating the morphological axis of the diaphysis is to adopt the method employed to indicate the tangent to the articular surface of the medial condyle. With the bone clamped in such a way that this tangent is parallel to the slab underneath and the lateral surface directed upwards, a long steel rod should be fixed to the lateral surface in the line of the morphological axis as estimated by the eye. The position of the two ends of this vertical rod would then be marked on the paper by the parallelograph. The two ends/

ends of the tangent having been marked, the four points are joined by two lines and the true Retroversion angle can then be measured.

The backward direction of the head of the tibia was first noticed by Collignon in 1880 in his "Description des ossements fossiles humaines". He said, "I insist strongly on the backward incurvation of the head of the tibia, which gives to the articular surface a direction oblique from above downwards and from before backwards. I am not aware that this character has ever been recognised. I consider it important to draw attention to it because it is sufficient to examine the skeleton of a gorilla to ascertain the same condition, but naturally exaggerated, involving in this anthropoid a state of demi-flexion of the leg and, as a consequence, difficulty in maintaining the vertical attitude".

He adds, further on, that it should be possible to deduce from the conformation of the bones of the leg a state of habitual flexion of this member, and, as a result, a gait less upright and less easy than that of actual man. This condition, in conjunction with the development of the biceps and the gluteus maximus, as indicated by the strongly-marked ridges of their attachments, would seem to indicate a certain aptitude for climbing.

In/

Fig. 13.

A eurycnemic European tibia and an Australian tibia from the lateral aspect. The difference in the size of the surface of origin of the tibialis posterior is apparent. Note also the difference in the general shape of the bones.

In an article published several years later Fraipont arrived at an analogous conclusion from the study of the femur in the race of Spy, "The strong incurvation forwards of the body of the femur, the enormous antero-posterior development of the articular surfaces of the condyles, authorise us to compare the attitude of this race in the upright position with that of creatures who live under the identical osteological conditions, namely, the anthropoids. The race of Spy, in the vertical attitude, ought to have the femur resting obliquely from behind forwards and from above downwards on the tibia, which is inclined somewhat from before backwards and from above downwards".

In 1888, the same author resumed the study of the incurvation of the head of the tibia and set himself to establish rigorously, by precise observations, the preceding conclusions expressed by Collignon on the subject of this character. After having assured himself that, in the semiflexed position of the lower limb in the anthropoids the plane of the articular surfaces of the head of the tibia is practically horizontal and that as a result the body of the tibia is inclined forwards, he next determined that the plane of the articular surfaces is equally horizontal in modern man in the vertical position. Then he set himself to estimate in tibiae of anthropoids, in those/

those of the race of Spy, and in modern human tibiae the angle which is formed by the axis of the head of this bone with the axis of the diaphysis. He was thus able to show that this angle of inclination of the head of the tibia varied from 20 to 28° in 6 anthropoids, from 8 to 14° in 25 Belgian neolothic tibiae, from 5 to 12° in 10 tibiae of Gallo-Romans and Franks, from 3 to 12° in 33 modern Belgian tibiae, and lastly that this angle measures 18° in the tibia of Spy.

M. Fraipont arrived at the following conclusions:-

1. The forward inclination of the tibia, in conjunction with the shape of the femur, is in relation with the attitude which the anthropoids adopt in the standing position.

2. The Homo of Spy had a tibia nearly as much inclined forwards as that of some female gorillas. He ought to have had, therefore, in the standing position an attitude less vertical then that of actual man.

3. A marked retroversion of the head of the tibia on the body of this bone is to be considered a simian character in the Homo of Spy.

4. This character seems to have been disappearing since the quaternary epoch.

5. The retroversion of the head of the tibia is probably in co-relation with an increased forward curvature of the body of the femur and with a carrying forward/

forward more and more of the anterior limit of the articular surface of the femoral condyles.

Manouvrier (90) did not agree with the conclusions of Fraipont and Collignon as regards the attitude of the men of Spy. He admitted that in the anthropoids the knee is somewhat flexed in the standing position. In this attitude the great abdomen and the curvature of the vertebral column tend to carry forward the centre of gravity and it is necessary to carry this back as far as possible by the inclined position of the femora. But it does not follow that complete extension at the knee is impossible in anthropoids and, indeed, in the movements of climbing and in the more common attitudes in which they support themselves by the hands, complete extension very often does take place.

It is almost obligatory to admit that the climbing animal from whom the human species are derived did not abandon freely his habitual mode of locomotion - which, as in anthropoids, must have been more or less quadruped - in order to adopt a biped mode of standing and of progression, so little related to the organisation of a climber. Obliged, doubtless, to live in a barren country and to walk more and more frequently on his two feet, it became necessary for him to take up an attitude which would be the least fatiguing and the most favourable to biped progression. It/

It was therefore the bending back of the trunk which must have commenced the transformation of the predecessor of man, the centre of gravity being in this way carried back to the vertical line.

But it is impossible to suppose that this predecessor, once the trunk had become curved, should continue to retain the lower limb in semi-flexion, since the extension of the limb, already possible in the climber, afforded him a solid support almost without muscular effort and permitted him to walk and run freely. The vertical standing attitude would therefore be acquired immediately with the bending back of the trunk. To demonstrate the necessity for the extension of the knee it is sufficient to stand or walk with the limb in the position of semiflexion for a short time. The expenditure of muscular energy is very great and the extensor muscles soon become fatigued. To rest these muscles it is only necessary to extend the limb.

The race of Spy are much higher in the biological scale than the anthropoids. The crania have a capacity more than double that of the largest of the known anthropoids. The bones of the upper limb are short in quaternary man. Even if their proportions are slightly different from those of the modern European, on the whole, they do not resemble those of * the anthropoids more than those of the African negro or/

or the Australian. In addition, the direction of the foramen magnum and that of the orbits do not indicate a different attitude from our own. From the examination of the cranium alone one can say that neither the vertebral column, nor the sacrum, nor the pelvis of quaternary man was disposed like those of the anthropoids. The race of Spy and of Neandertal had, therefore, the curvature of the trunk; they were able to utilise the complete extension of the knee in the standing position, in walking, and in running. They utilised it and were able to hold themselves as erectly as modern man. It is very probable that at the quaternary epoch man had been for long in possession of the perfectly biped and vertical attitude which is possessed to-day by races the most savage and the most backward from the point of view of intellectual and morphological development.

It remains to reconcile the retroversion of the head of the tibia with the completely erect attitude. Manouvrier showed that although the plane of the articular surface is horizontal in the anthropoids, a retroversion of the head of the tibia does not interfere with the erect attitude. The knee-joint may be completely extended in spite of the backward direction of the head of the tibia. In this position the mechanical axis of the tibia is vertical and the femur/

femur is supported on the sloping articular surfaces of the tibial condyles. At first sight it would seem that the femur would have a considerable tendency to slip backwards but this is prevented by various factors; the menisci are thicker behind than in front and this helps to diminish the obliquity of the articular surfaces of the tibia; the articular surface of the medial condyle is in reality concave so that its posterior part presents a plane less inclined than its anterior; the means of fixation of the articulation, again, are sufficiently powerful to prevent any slipping, viz., the crucial ligaments, the lateral and posterior ligaments, reinforced by the tendons of the neighbouring muscles.

Manouvrier measured the angle of inclination and the angle of retroversion in a large number of tibiae from very varied sources. He found that retroversion of the head of the tibia was met with in practically all the races examined, from neolithic man to modern Parisians and modern savage races. Since there is no question as to the erect attitude of these latter races, there is no doubt as to the association of the condition with the vertical gait. On the whole, it is less pronounced in the human species than in anthropoids and seems to have diminished in degree since prehistoric times. In the majority of the neolithic specimens and even in modern Parisians a greater angle of/

of inclination was met with than in the tibia of Spy, so that it is not possible to regard the retroversion in the Spy tibia as an intermediate form between the anthropoids and man. Retroversion is more pronounced and more accentuated in savage races than in the modern European, and, in general, is more marked in non-European races than in European. Manouvrier found a close association between the conditions of retroversion and platycnemia; he found that, on the whole, the degree of the one change corresponded to the degree of the other.

Manouvrier next proceeds to show that retroversion of the head of the tibia instead of being a hindrance to the erect attitude is actually in favour of it. In the modern European in the standing position, the femur and tibia do not lie in the same straight line but form with each other an obtuse angle which is open forwards. It is probable that variations in this classical angle are possible even with a completely extended knee. The most important cause of such variations will be variations in the lumbar curvature. If one stands in such a way that the lumbar curvature is somewhat diminished, the knee joint being in extension, and if one passes from this attitude to one in which the lumbar spine is strongly curved, carrying the pelvis forwards, it is seen that the direction of the lower limb is considerably modified. It becomes oblique from above downwards and from/

from before backwards. The converse is produced if one passes from the strongly curved to the less curved attitude. Since the lumbar curve is a human character and liable to considerable variation, Manouvrier assumes that it was probably less marked in quaternary man than in the modern European.

The erect attitude in the perfect biped demands a minimum of muscular contraction while the femur and the tibia form a column of support. It is necessary and it suffices for this that the mechanical axis of the femur and that of the tibia should be directed in such a way that a force applied vertically to their upper extremities will not tend to incline the femur backward or the tibia forward. The mechanical axis of the femur must therefore be at least vertical in an antero-posterior plane; the same holds for the tibia. But if the femur should be a little inclined forwards and the tibia a little backwards, the stability of the attitude will only be better assured, since the two bones are inclined each in the direction opposite to that in which the weight of the body tends to bend it.

If we assume with Manouvrier a lesser degree of lumbar curvature in quaternary man with the femur more or less vertical instead of being inclined forwards, it is obvious that the retroversion of the head of the tibia will increase the solidity of support of the lower limb. The mechanical axis of the femur/

femur and the tibia being vertical, the femur will be supported on the inclined head of the tibia and there will be less likelihood of the femur passing backwards or the tibia forwards - i.e. of flexion occurring at the knee-joint.

This effect of retroversion has been surpassed and rendered unnecessary by the accentuation of the lumbar curvature which has taken place since the time of quaternary man. The increase in the lumbar curvature has been acquired, since it provides the attitude in which the erect posture can be maintained with the least fatigue. We have seen, experimentally, that the effect of the greater lumbar curvature is to carry the femur forward on the tibia and produce the obtuse angle between the two bones. The effect of this angular relationship between the two bones on the stability of the knee-joint will be the same as that of retroversion of the head of the tibia - the centre of gravity falling in front of the centre of the joint, there will be no tendency to flexion of the joint in the erect attitude.

Having considered the relation of the retroversion of the head of the tibia to the attitude of the limb, Manouvrier proceeded to formulate a theory to account for the existence of this character. He did not believe that it was simply a legacy inherited from an ancestral species but considered it more likely/

likely to be related to physiological and mechanical conditions. He drew attention to the gait adopted at the present day by many peasants and especially by inhabitants of mountainous countries. These individuals find that the least fatiguing method of walking over hilly and irregular ground is to walk with the knees slightly flexed, and, indeed, this condition is well seen in many hill-shepherds and ghillies in this country. On this kind of ground, and especially on going up-hill, it is impossible to keep the trunk well back in such a way that the knees can be freely extended and it is the greatest relief to walk with the knees somewhat flexed. When walking on level ground the expenditure of muscular energy by an individual who has acquired the habit of walking in this way will be greater than that of one who walks in the ordinary manner, since, in the former case, the muscles of the thigh have to support at each step the weight of the body in order to produce the extension which succeeds the flexion. But the advantage in hilly country is great and the gait is acquired by anyone who lives in such a country for a length of time. There can be no doubt that man of the quaternary epoch lived under the same conditions which, to-day, oblige so many individuals to adopt ordinarily or frequently the habit of walking with the knee in semi-flexion. It is to be presumed that quaternary/

quaternary man would have the same habit, but it is to be noticed here that the flexion takes place only during walking; when standing the individual is perfectly erect and the knee-joint is perfectly straight. If we assume this method of walking "en flexion" to be the cause of the retroversion, it will serve to explain the close relationship between this condition and that of platycnemia, since both characters are produced by the conditions of life in a difficult country.

Manouvrier illustrates the mechanism of the change in a somewhat convincing manner. He shows that the superior articular surface of the tibia lies not in the prolongation of the axis of the bone but posterior to it, so that pressure applied to this surface will tend to cause bending backwards of the upper end of the bone. When the knee is semi-flexed, as in the manner of walking above mentioned, the weight of the body will tell especially towards the posterior part of this surface and increase the tendency to bending. In some cases the body of the bone is unable to resist this strain and a bending of the diaphysis results - the change which is known as retroflexion. In the majority of cases the bending takes place very slowly and affects only the region of the epiphyseal cartilage; indeed, in most cases, the resulting condition is more an interference with the/

the growth of the posterior part of the cartilage from compression so that the upper part of the diaphysis becomes oblique and the epiphysis is fitted on at an angle, being tilted somewhat backwards.

There can be no doubt that the destructive portion of Manouvrier's work is perfectly sound, that individuals with retroversion of the head of the tibia walk perfectly erect, and that retroversion rather gives stability to the lower limb than otherwise. The explanation which he suggests as to the cause of the retroversion is very ingenious but in view of other work it does not seem acceptable. Havelock Charles (94) showed that the change occurred to a well-marked degree in the natives of the Punjab who are dwellers in a level plain and whose gait, in the words of this author, is "as erect as that of a Guardsman." He believed that the retroversion was due to the habit of extreme flexion of the joint in the attitude of squatting, acting from the earliest childhood. The ligament of the patella has its attachment to the diaphysis. In complete flexion, before the junction of the epiphysis to the shaft, the tension of the ligament posteriorly upon the front of the former would have a tendency to push it backwards. He showed that the squatting posture, which is adopted by natives of Eastern and savage races during many hours of the day both at their work and during their/

their leisure, has a profound effect on the conformation of the tibia. In this attitude (see Fig. 18) the back of the thigh rests upon the calf, the front of the tuber ischii being in close apposition with the heel; in fact, the trunk weight is supported by the heels, the extreme flexion of the hip, knee, and ankle allowing of this. The heels are apart about the distance that separates the ischial tuberosities. Another attitude frequently adopted by the Punjabis he called the sartorial position (see Fig.19); the person sits with his legs crossed in the traditional "tailor" attitude, the body weight resting on the tuberosities of the ischium, the external malleoli, and the outer border of the legs. In both attitudes there is extreme flexion at the knee joint.

Charles showed also that retroversion was present in the Punjabi infant and regarded it as a character inherited from ancestors in whom it had persisted or been acquired as a result of the squatting attitude. The association with the retroversion in the foetus with other features which result from the squatting attitude, namely, additional facets for the talus and convexity of the lateral condyle, favour this conclusion. As the child grows up the backward curvature will naturally be preserved, since the child adopts the squatting posture at an early age.

Hueter (62) traces back the retroversion of the head/

head to the flexed attitude in the uterus. In this position the posterior part of the articular surfaces of the tibia alone comes into contact with the femur, while the anterior part of the tibia does not come into contact with the femur and is therefore free from the pressure which acts on the posterior portion. Owing to this difference in pressure the anterior part of the diaphysis exhibits a relatively greater growth in length than the posterior and the epiphysis is naturally canted backwards.

G. Retzius (00) pointed out that the condition of retroversion is present in the foetus and child of modern European races. The change is most marked about the sixth month and rather diminishes towards the end of pregnancy. By the end of the first year of life the retroversion has almost disappeared in the European child. Hultkrantz (98) explains the disappearance of the retroversion in the infant by the enforced extended position in which it lies. Retzius is inclined to consider this peculiarity of the tibia in Europeans as a reminiscence of the earlier stages of their history and not simply the result of mechanical conditions during intra-uterine life. Klaatsch agrees with the opinion of Retzius.

It is clear, then, that the child of both European and savage races is born with a backward displacement of the upper end of the tibia. I found this/

Fig. 18.

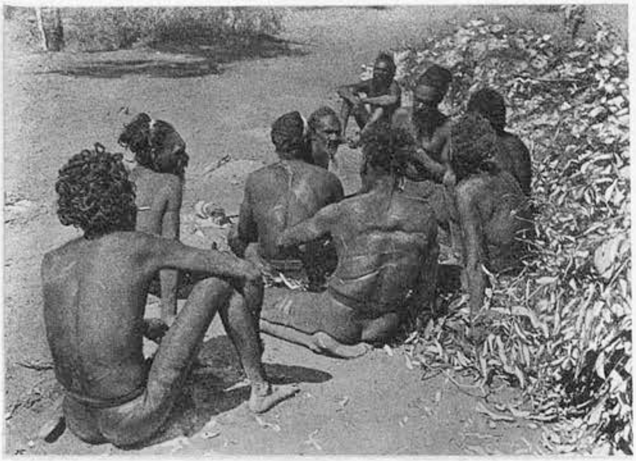
Showing the squatting attitude occasionally adopted by the Australian aborigines.

Fig. 19.

Two photographs illustrating the "sartorial attitude".

this change well-marked in the tibiae of one or two Australian infants which I was able to examine. I made an examination also of the bones of some older children in order to ascertain the variations in the amount of retroversion at different ages, but the number of specimens was too limited to come to any definite conclusion on this point. In tibiae between the age of about ten to fourteen I found definite retroversion in some cases while in others the tibia was practically straight. It is difficult to arrive at a conclusion as to the explanation of the retroversion in the foetus and infant, but the facts would seem to indicate that it is most likely an inherited, and not merely a mechanical, character. The association of the condition with other characters which could only be inherited, e.g. facets on the distal epiphysis for the talus, is very significant. If we remember also that the foetus at the period of pregnancy at which the change is most marked, i.e. about the sixth month, is subjected to almost no real pressure, being freely suspended in a sac of ammotic fluid, it becomes extremely improbable that mechanical forces are the cause of this peculiarity.

For the retroversion of adults it would seem that the explanation which is given by Havelock Charles is correct - that the preservation of the change depends upon the extreme degree of genuflexion which/



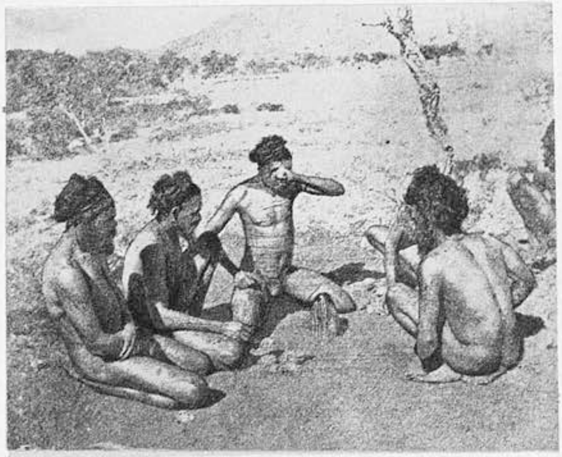
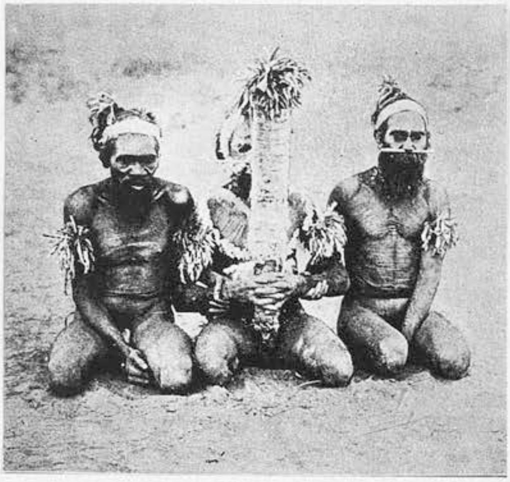


Fig. 20.

Photographs illustrating the most common attitude of repose among the Australian aborigines. Not the extreme flexion at the knee and the position of the feet.

which is present in the habitual attitudes adopted by races presenting well-marked retroversion. The suggestion of Manouvrier, that the condition was due to the "marche en flexion" was nullified by the demonstration of the change in individuals who did not employ this gait. The present series of Australian tibia gave an average inclination angle of 13°, which forms a marked contrast with the average angle in Europeans of 5 - 6°, so that it should be of interest to discover if the conditions of life in the former conform with the explanation brought forward by Havelock Charles. Among the Australian aborigines the use of the chair, of course, is unknown. In Figs.18 to 25 are illustrated the attitudes which they commonly adopt while resting and at work. It will be seen from Figs. 18 and 19 that the squatting and sartorial attitudes described by Charles are both employed, but the most common posture which they take up is very characteristic. Figs. 20 to 22 illustrate this position. It is apparent that here the individual practically sits on his feet; the knees are directed forwards in the position of acute flexion and rest on the ground; the thigh is in contact with the calf and the weight of the body is transmitted through the thighs to the back of the leg and thence to the ground practically through the whole length of the leg proper and through the feet. The position of/



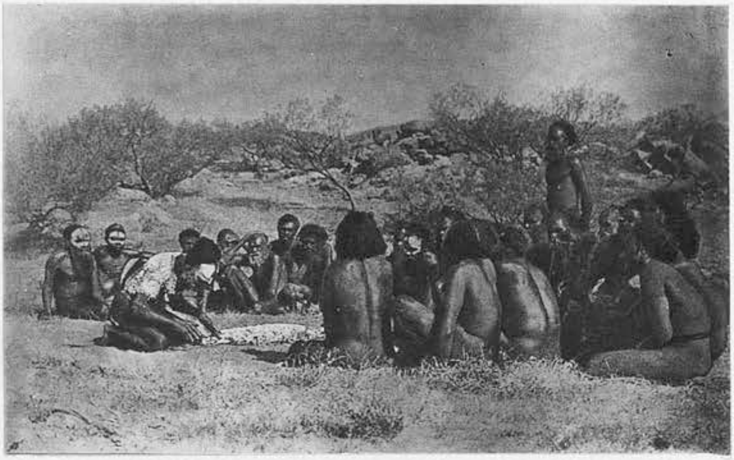



Fig. 21.

Further examples of the same posture.

of the feet varies; in the majority of cases they are tucked underneath the buttocks and the person sits on the inner borders of the feet, the outer borders resting on the ground (see Figs. 20 and 21); in other cases the individual sits on the heels and the foot may be either acutely dorsi-flexed at the ankle joint or may be plantar-flexed so that the dorsum of the foot rests on the ground. Other occasional attitudes will be seen in some of these photographs. The attitude adopted by the females corresponds to that described by Dr St. John Brooks and quoted by Arthur Thomson with reference to Zulu girls. They sit with the buttocks and one thigh on the ground, with the knees flexed, and the legs directed towards the opposite side (See Fig. 24). But the females also sometimes take up that attitude of extreme genu-flexion described as the most common position for the male. In all cases the extreme degree of flexion at the knee is very striking. The effect of these various attitudes in the direction of retroversion will be the same as that of the squatting posture; the tension on the ligamentum patellae which must result from the marked degree of flexion at the knee will have the same tendency to push the epiphysis backwards.

The photographs are reproduced from "Native Tribes of Central Australia", and "The Northern Tribes of/

Fig. 22.

Showing variation in position of feet.

Fig. 23.

Other positions. In all of these the extreme flexion at the knee is very striking.

of Central Australia" by Spencer and Gillen, and from "The Native Tribes of the Northern Territory of Australia" by Spencer.

The explanation of Charles is, therefore, satisfactory so far as non-European cases are concerned. How are we to account for those cases of well-marked retroversion which undoubtedly occur in European races, as was pointed out by Manouvrier and Macrae Aitken? Manouvrier obtained an angle of inclination as great as 15°. In 118 European tibiae I found well-marked retroversion present in 10 specimens. Macrae Aitken explains the presence of this character as a persistence of the foetal retroversion, but experience has shown, that so far as the adult bone is concerned, we should be extremely chary in ascribing to inheritance a feature, the presence of which can be explained by physiological causes; we have seen that platycnemia is not simply a legacy from a simian ancestor. If the attitude of squatting or other similar posture serves to account for the retroversion of Oriental and savage races, is it not possible that the positions adopted in certain occupations for prolonged periods and from early life will have exactly the same effect? If we take, for example, the occupation of a miner, in which the individual commences work while the bones are still growing and takes up attitudes of squatting or kneeling during many hours of the day, there seems no/

Fig. 24.

Position frequently adopted by females, mentioned on Page 83. The weight rests mainly on the buttock and thigh of one side.

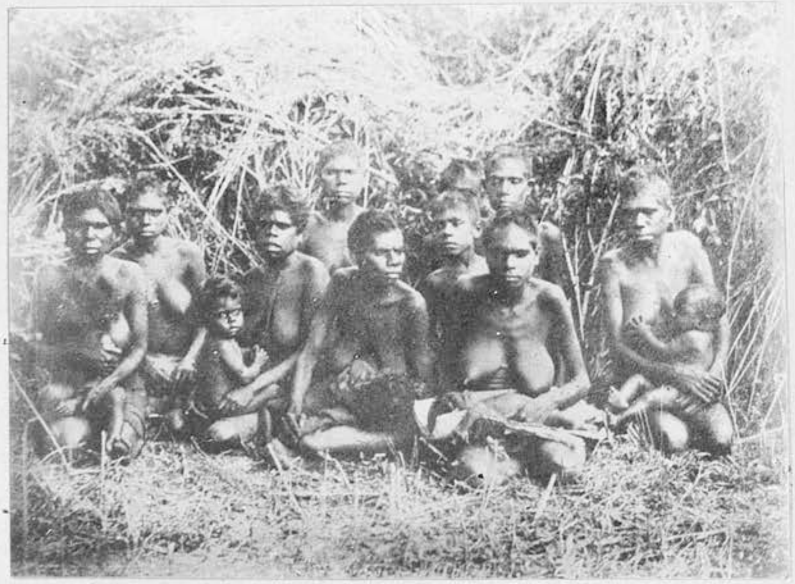


Fig. 25.

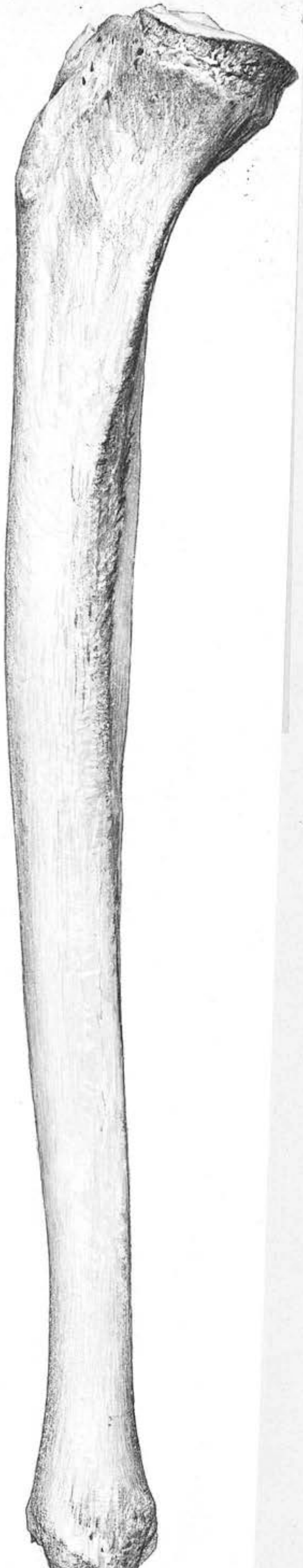
Other attitudes adopted by females.

no reason why the effects of these positions on the bones of the leg should not be the same as in non-European races. Here also, is there extreme flexion at the knee with, as a result, increased traction on the ligamentum patellae and there must be a similar tendency to backward displacement of the epiphysis.

Another point which requires consideration is the frequent association of retroversion with platycnemia. Manouvrier considered that both changes depended on life in a mountainous and irregular country. But although such conditions of life prevail with many races who show a well-marked degree of both these features it does not follow that these features are both the result of that circumstance. It is obvious that a race living under the conditions which produce a hypertrophy of the tibialis posterior and platycnemia is likely to be primitive in its habits and, instead of employing the chair in sitting, to assume during repose those attitudes which bring about retroversion. The causes of the two conditions do not appear to be more closely related unless we accept that, in the special posture of squatting, there is a greater strain on the tibialis posterior and a tendency to hypertrophy of the muscle and platycnemia from this cause. Indeed, it would appear that in inhabitants of a plain such as the Punjabis, the hypertrophy of the tibialis posterior and the resulting platycnemia depend/

Plate III.

An Australian tibia showing well-marked retroversion. A certain amount of the backward displacement of the whole proximal epiphysis which is referred to later is also to be observed. Note also the slender appearance of the distal epiphysis and the conical outline of the malleolus.



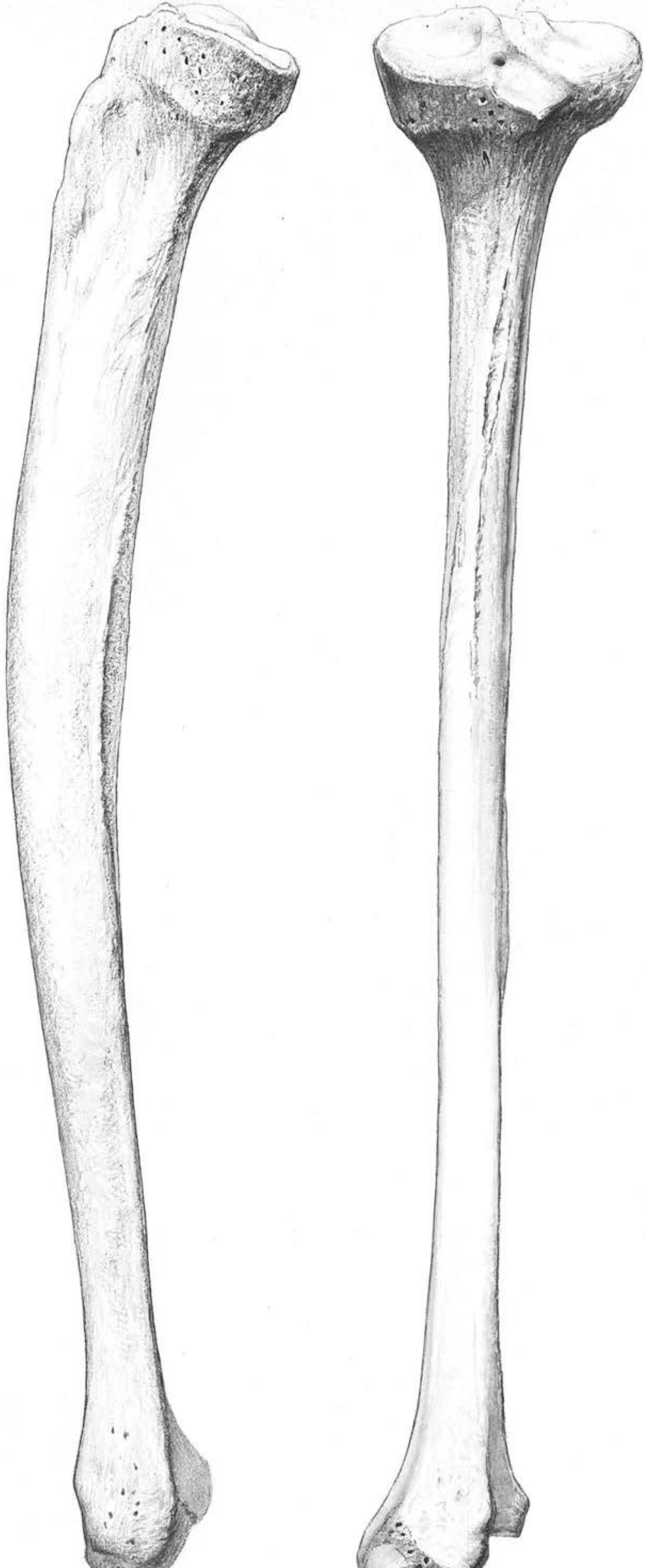
depend entirely on the squatting posture. But the squatting attitude is by no means the only, or the most important, cause of hypertrophy of the muscle and platycnemia since the change occurs to a well-marked degree in races, such as the Australians under consideration, who adopt other attitudes of repose more frequently than squatting, which do not cause any increase of strain on the tibialis posterior.

It will be of interest to compare the degree of retroversion in the Australian tibia with that of other races. Martin gives the following measurements:-

	Retroversion angle.	Inclination angle.
Swiss	7.6°	5.3°
Bajuvar	8.8°	6.6°
Parisian (S.Marcel)	9.5°	6.5°
Senoi	10.8°	7.6°
Neolithic in general	11.2°	8.6°
Paltacalo Indian	13.7°	10.2°
Swabians and Alamanns	14.2°	11.4°
New Caledonians	14.9°	11.6°
Neolithic of Orrouy	16°	12°
Gibraltar	16.2°	——
Low Californian	16.7°	13.3°
Spy I.	18°	13°
Fuegian	20°	16.5°
Californian	20°	15°

Plate IV.

Posterior and medial views of a tibia with well-marked retroflexion.



*

La Chapelle-aux-Saints	20°	14°
La Ferrassie	20°	17°
Anthropoids	26°	12-25°

In the Australian bones the Retroversion angle was 17° and the Inclination angle 13°, so that they occupy a very high position so far as the degree of this change is concerned. The only modern races presenting a higher angle are the Fuegians and the Californians. As mentioned previously, the contrast with the small angle of the European groups is very marked.

Many authors in describing the backward direction of the proximal end of the tibia make no distinction between retroversion and retroflexion. As already stated, the diaphysis in the former condition is straight, whereas in the latter it presents a backward curve in its proximal third or so. This change is well illustrated in Plate IV . Manouvrier shows that, since the superior articular surface of the tibia lies normally behind the prolongation of the axis of the diaphysis, there will be a constant tendency to flexion of the diaphysis. This force will be most marked where the tibia is inclined forwards as in running downhill or leaping. The tibia in certain individuals is unable to resist the strain and a certain amount of bending of the diaphysis takes place./

place. He found that the change occurred most frequently in platycnemic races and that the individuals presenting it were usually robust and muscular.

Klaatsch emphasises the importance of distinguishing between retroversion and retroflexion. He believes that, although the two variations are closely related, they are dependent on different states of erectness of the tibia. He noticed in European tibiae a slight concavity of the anterior border, the starting point of the concavity being at the same level as the commencement of the backward bend in a retroflexed bone. He found retroflexion especially marked in the Veddah tibia. He suggests that races presenting this feature may represent an intermediate stage between the men of Spy and the modern European or, on the other hand, that the European tibia may represent a line of development in one direction and the retroflexed tibia development in another, both having originated from the same starting-point, the condition of which is supposed to resemble the tibia of Spy, for the latter is not so strongly bent towards the back as in the case of the Veddahs and can be clearly distinguished from the tibia of recent Europeans.

In order to verify the observation of Klaatsch as regards the concavity of the anterior border of the European tibiae I made an inspection of the series of/

of 118 European tibiae which I have previously mentioned. I found that in the majority of cases there is very much the appearance described. In most bones it was not so much a concavity as a gradual slope of the anterior border forwards towards the elevation of the tuberosity. It seemed to me that the condition was probably to be accounted for by the relatively great sagittal diameter of the proximal epiphysis.

The change of retroflexion was not very common among the Australian tibiae and occurred definitely in only 31 specimens out of the 236; in 6 bones the condition was distinct and well-marked, in 3 it was very marked, and in the remaining 22 it was only slight. The curve in nearly all cases commenced about the junction of the upper and middle third of the diaphysis. I was able to verify the observation of Manouvrier that retroflexed bones are robust and show well-marked muscular impressions. The average cnemic index for the 31 retroflexed specimens was 64.9, so that the association of the peculiarity with platycnemia was not present. Indeed, 4 of the bones had an index of over 70.

Owing to the deficiency in observations in connection with this character it is not possible to come to a definite conclusion regarding its significance. The suggestion of Manouvrier that the change is the result of forces tending to bend the bone in a/

a sagittal direction would seem to be nullified by the fact that the condition occurs chiefly in bones which are relatively massive and strong. In addition, the nature of the curvature does not correspond to that which results in pathological conditions in which the bones are softened and yield to bending forces, as in rickets or ostitis deformans; in such conditions the sagittal curvature involves the whole length of the diaphysis and is not limited practically to the upper third as in retroflexion. It will be of importance to accumulate more facts in connection with this change in future observations on the tibia.

CONVEXITY OF THE ARTICULAR SURFACE OF THE LATERAL CONDYLE.

I shall consider next two peculiarities which are frequently associated with retroversion of the proximal extremity of the tibia and which are apparently dependent on the habitual posture of the individual, namely, increased convexity of the articular surface of the lateral condyle and the presence of articular facets on the anterior border of the distal epiphysis for articulation with the talus.

In Cunningham's Textbook of Anatomy the articular surface of the lateral condyle is described by Hepburn as slightly concave from side to side and gently convex from before backwards; its circumference is well-defined/

well-defined in front, but is rounded off behind, thus markedly increasing the convexity of its posterior part. Attention was first drawn to an increase in this antero-posterior convexity under certain conditions by Arthur Thomson in 1889. He showed that in Oriental and savage races who habitually adopt the attitude of squatting the convexity is considerably increased. He maintained that the explanation of this fact depends on the physiology of the knee-joint. The lateral meniscus of the joint differs in regard to its attachments from the medial meniscus in being more loosely connected and possessing a wider range of movement. To facilitate this movement the articular surface of the lateral condyle of the tibia is convex and its posterior border is especially rounded off. Thus, the lateral meniscus is permitted to move backward and forward more freely. This backward and forward movement of the meniscus takes place in flexion and extension, coincident with a certain amount of rotation. In the position of squatting, it has already been shown how the back of the thigh rests upon the calf and the knee-joint is in a state of extreme flexion, associated with a certain degree of rotation of the leg upon the thigh. This is just the position in which the lateral meniscus is drawn downward and backward, and an increase in the convexity of the condylar surface must considerably facilitate/

facilitate this movement. The artieular surface is flattest in those who do not as a rule make use of the position of squatting, whereas it is markedly convex in those races who do habitually adopt it.

Thomson made his observations by moulding a strip of soft lead across the centre of the articular surface of the lateral condyle in the antero-posterior direction; from this he was able to take a tracing. He then arranged the tracings into five groups according to the degree of curvature they displayed. He numbered the groups from 1 to 5 and was thus enabled to get a series of curves for comparison (see Fig.26). In the present investigation the tracings were made directly on paper by means of the Perigraph and this instrument enables one to make exact reproductions of the curvature of the articular surface. In some cases the lateral condyle was diseased or mutilated and only 218 out of the 236 tibiae were available for this purpose.

The following series has been obtained from different races:-

Negro	1.3	
European	1.5	
Neandertal Homo	1.5	
Fuegian	2.3	
Australian	2.5	(Thomson)
Punjabi	2.5 to 3	
Indian	2.6	

Andaman Islander	2.7
Peruvian	3
North American Indian	3.2
Orang	3.3
Gorilla	3.4
Chimpanzee	3.5

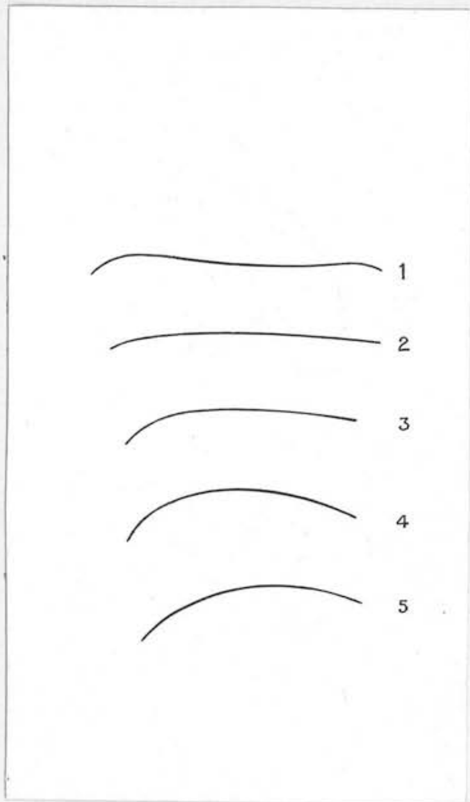


Fig. 26.

The highest curve obtained by Thomson was one of 5 in an Andaman Islander. The marked degree of convexity in the anthropoids is probably to be explained from the flexed position of the lower extremity.

The average curve in the present series corresponded to 2.3 of Thomson's scale, which is slightly less/

less than the figure he obtained. A few bones presented a convexity corresponding to the 4th type; six specimens presented curves corresponding to the 1st type. Many of the tracings exhibited not only a rounding off of the posterior border of the condyle but of the anterior border also, though the convexity in front was always less marked than that behind. The tracing which was taken transversely across the condyle showed clearly the very gradual rise towards the intercondyloid eminence, so that in this way, as was pointed out by Humphry, the antero-posterior convexity of its medial portion is increased. The tracing showed also that the condyle is slightly concave in the transverse direction (see Fig. 27).

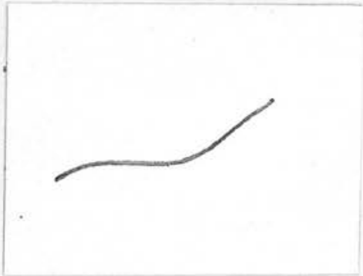


Fig. 27.

It may be pointed out that, since the increased convexity of the lateral condyle is well-marked in the present Australian series, the classical attitude of squatting is not essential for its production. The essential cause is extreme flexion at the knee and any attitude by which this position of the joint is maintained will suffice to produce the convexity; we have seen that the most common attitude among the Australians is not squatting but rather a combination of a kneeling and a sitting posture.

In the table given above it will be seen that in the Negro and the Homo of Neandertal the articular surface is almost flat although the causal factor of habitual extreme genuflexion was presumably present in both. Thomson believed that in these cases a smaller convexity was compensated for by a greater retroversion of the head of the tibia dispensing with the arrangement whereby the lateral meniscus may glide back more freely in the flexed position. Havelock Charles doubted the correctness of this opinion since he found in the Punjabi that considerable retroversion and a well-marked convexity might be present in the same specimen; he thought it unlikely therefore that a greater degree of retroversion was compensatory to a flat lateral condylar surface. Nor did he find that retroflexion was present as a compensatory change in specimens with a flatter condylar surface. He made/

made no actual measurements as to the degree of retroversion. In order to clear up this point, namely, as to whether a lesser degree of convexity is compensated for, by a greater degree of backward inclination of the proximal extremity, I investigated the relationship*between the two conditions in the present series. In a group of 25 tibiae, the convexity of those lateral condylar surface corresponded to No. 3 of Thomson's types in 22 cases and to No. 4 in 3 cases, the angle of inclination varied from 8° to 26°, the average angle for the group being 14.8°, an angle only slightly greater than the average inclination angle of 13°. In a second group of 12 bones, whose convexity would correspond to No. 1 of Thomson's types in 3 cases and to 1.5 in the remaining 9 specimens, the angle of inclination varied from 9° to 20°, the average angle being 14.2°. It would appear, therefore, that neither the low degrees of the convexity nor the high degrees are associated with an amount of retroversion very much above the average. There is certainly no compensation between a low variety of convexity and a high degree of retroversion. The low degree of convexity in the Negro and in the Spy Homo remain in the meantime unexplained, But the group of Negro specimens from which Thomson obtained the average curvature of 1.3 consisted only of 7 members and in a later investigation he found that the average/

average curvature in 5 specimens was as high as 3, so that it may be doubted as to whether 1.3 is a true indication of the average amount of curvature in Negro subjects. In the case of the Neandertal specimen it may be pointed out that the articular surface of the femoral condyles is very extensive in the antero-posterior direction, and it is conceivable that, owing to this fact, there would be less tendency for the lateral meniscus to be carried backwards during flexion of the joint, the great length of the condyles permitting an extreme degree of flexion without the necessity for this change.

As regards the relationship of this increased convexity of the lateral condyle of the tibia to platycnemia, Thomson found that, as a general rule, the two conditions occurred together, but he believed that this relationship was rather due to a coincidence than to any direct association; those individuals who habitually squatted were usually also exposed to the influences which produce platycnemia - hunting in uneven country, etc. In the group of 25 bones mentioned above, with high degrees of convexity, the cnemic index varied from 51.9 to 86.2 which was the highest index of the whole series. This specimen with the high index presented a convexity corresponding to No. 3 of Thomson's types. Six members of this group had an index of over 70. The average index for/

for the group was 65.9 which differs very little from the average index of 65.2 for the whole series. Similarly, in the 12 specimens with a low degree of convexity the index varied from 58.8 to 72.4, the average index being 65.6. It is evident, therefore, that so far as the present series is concerned, there is no constant relationship between the degree of convexity of the lateral condyle and the degree of platycnemia. Indeed, if we accept Manouvrier's theory as the correct explanation of platycnemia and the habitual posture as the cause of the increased convexity, there is no reason why there should be a close relationship between the two conditions, except possibly, in races such as the Punjabis where the platycnemia may depend on the classical attitude of squatting alone, the usual causal conditions being absent.

ARTICULAR FACETS ON THE ANTERIOR MARGIN OF THE LOWER EPIPHYSIS.

The presence of this peculiarity was first recognized by Arthur Thomson in 1889. In the European tibia the anterior margin of the distal epiphysis, i.e. the border between the articular surface and the anterior surface, is usually sharp and well-defined, whereas in the tibia of most of the primitive forms it/

it usually presents a facet, more or less distinct, placed towards the fibular side and encroaching on the margin in such a way as to become directly continuous with the surface which articulates with the upper surface of the body of the talus. If the talus belonging to the same specimen is examined, it will be found that the neck of that bone fits accurately into this facet in extreme dorsiflexion of the foot, and that not infrequently the back of the talus is provided with a corresponding facet. In regard to the tibial facet there are many differences in form and extent. In some cases the presence of such a facet is only indicated by an eversion or lipping of the anterior margin of the inferior articular surface; in other instances, this eversion of the margin is associated with a hollowing of the bone around it, the surface of which is smooth but can hardly be regarded as articular. In these cases we not infrequently find that there is a tubercular ridge on the neck of the talus, the surface of which is smooth, which in extreme flexion of the foot, fits into this hollow, the surfaces of the bones being in contact. In many specimens, however, the articular facet is well-marked and defined and varies only in size and form. The explanation suggested for this appearance by Thomson was the marked dorsiflexion at the ankle joint produced by the attitude of squatting. Havelock Charles/

Charles (94) described also a second facet of a smaller size, occupying a more medial position. He ascribed it to the same cause.

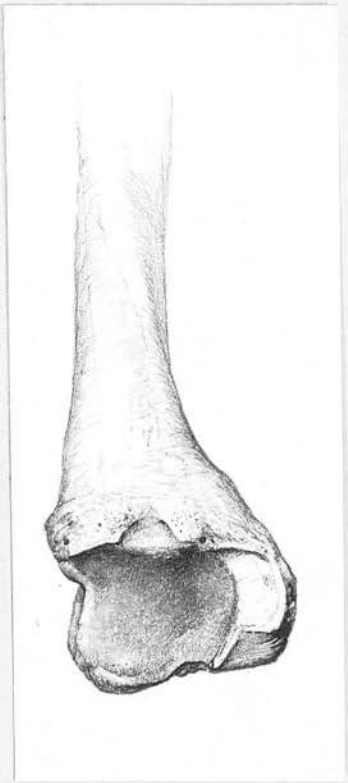
The frequency of the occurrence of the two facets is indicated in the following table:-

Lateral facet.			Medial facet.		
Australian	78%	(Thomson)	Punjabi	47.2%	(Charles)
Punjabi	64%	(Charles)	Egyptian	19.0%	(Sewell)
Andaman	55%	(Thomson)	Orang	86.6%	"
Egyptian	88.6%	(Sewell)	Chimpanzee	66.6%	"
European	½%	(Pfitzner)	Gorilla	16.5%	"

Charles found that in the Punjabi the lateral facet is the more frequent and the larger of the two. Thomson described only the lateral facet. If we remember that the foot is carried outwards in the attitude of squatting it is not astonishing that the lateral facet is more frequently present. Regnault (98), however, points out that, not only the squatting posture, but any position in which there is maintained extreme dorsiflexion at the ankle-joint may bring about this condition. In the anthropoids, with the possible exception of the Gorilla, the facets are of frequent occurrence. In their case it is probable that, whilst the cause is the same, i.e. extreme dorsiflexion of the ankle-joint, the production of that flexion is due to a different use of the foot than in man, since the anthropoids do not squat like men./

Plate V.

The lower extremity of an Australian tibia showing the lateral facet for the talus. In the position in which the medial facet is sometimes found a distinct hollow is apparent.



men. The dorsiflexion is probably dependent on the free use of the foot in climbing, in which act, no doubt, the weight of the body is for lengthened periods sustained by the foot with the ankle-joint in an extreme state of flexion.

In the present Australian series the lateral facet was nearly always to be made out; it was very exceptional to find it completely absent. I found it distinctly present in 190 out of the 236 bones. The appearance is seen in Plate V . The medial facet occurred alone only twice and occurred in association with the lateral facets in 3 specimens. The contrast between the frequency of the appearance of this facet in the Australians and the Punjabis is probably to be explained by the difference in the most common attitudes of these two races; in the most common position of the former the dorsiflexion at the ankle is relatively less than in the classical squatting attitude of the Punjabis. When the feet are tucked in underneath the buttocks so that the individual sits on their inner borders the dorsiflexion at the ankle is not marked, so that the medial side of the neck of the talus does not reach the anterior border of the distal epiphysis, as one might expect.

It is interesting to note that similar facets are occasionally present in the European tibia. Thomson observed this fact and found the appearance in only

2/

2 specimens out of a group of 30 tibiae. Macrae Aitken referred to the condition in Scottish tibiae. Regnault has discussed the appearance also in regard to modern French tibiae. In the series of 118 European tibiae I found the lateral facet present in 20 specimens; in 7 cases it was well-marked and in the remaining 13 only faintly marked. The frequency in this series was therefore considerably higher than the figures given by Thomson or Pfitzner. The medial facet was only present in 2 cases and in both it was only feebly marked. In no instance did the two facets occur together. In order to account for the presence of this feature in European bones, in the absence of the habitual use of attitudes such as squatting which produce extreme dorsiflexion at the ankle-joint, Regnault makes the statement that such appearances depend not only on extreme degrees of movement in a joint but also on the shape of the articular extremities of the bones which enter into the formation of the joint. He endeavours to prove this assertion by the appearances seen in certain pathological conditions, such as mal-united fractures, congenital dislocation of the hip, and rickets, in which an alteration in the shape of the joint cavity has taken place and an extension of the articular surface on to the neighbouring bone has resulted. This appearance is seen especially after mal-united fracture of neck/

neck of the femur where the angle of the neck has become diminished; in such cases the articular surface extends for some distance on to the anterior and upper aspect of the neck. He assumes, for what reason he does not state, that in certain individuals the shape of the joint cavity differs from the normal in such a way that contact is possible between portions of bone, normally non-articular, which are adjacent to the true articular surface. He states that in the ankle-joint this contact is the result either of an elevation of the antero-superior part of the talus so that it comes more readily into contact with the anterior border of the lower end of the tibia or to a less-degree of convexity of the superior surface of the talus so the neck is permitted to come more readily into contact with the tibia. But M.Regnault fails to take into account the possible influence of occupation in determining peculiarities in the bones of modern Europeans. The work of Lane, referred to above, has shown how great is the importance of this factor. Heredity having determined the general shape of the bone, the development of the modifications peculiar to the adult bone depends on very definite mechanical and physiological factors. Thomson had already suggested that the facets in question might be developed in such occupations as that of a miner where attitudes involving extreme dorsiflexion at the/

the ankle are maintained for prolonged periods. There seems every reason to believe that the facets occurring in European tibiae are to be explained in this way.

The association of facets on the anterior border of the distal epiphysis of the tibia with an increased convexity of the articular surface of the lateral condyle is to be explained by the marked degree of flexion which occurs at both these joints in the habitual attitudes of the race under consideration. But the two characters are not necessarily dependent on each other; if we examined a race in which a marked genuflexion occurred in the common posture without marked dorsiflexion at the ankle-joint we should probably find an absence of the facets on the anterior border of the distal extremity. The relationship to platycnemia is still less direct. Although the two characters frequently occur together, the association, as in the case of the convexity of the condylar surface, is more or less accidental and due to the fact that races exposed to the conditions producing platycnemia habitually take up attitudes involving extreme dorsiflexion at the ankle joint. In these cases in which the facets in question were absent the cnemic index varied from 56.8 to 83.7, the average index for the 46 bones being 66.7, so that there is no relationship between an absence of this facet and a lesser degree/

degree of platycnemia, as would have been expected if the conditions had been due to a common cause.

Another feature described by Havelock Charles in connection with the modifications of the tibia which result from the squatting attitude is an obliquity of the articular surface of the medial condyle. He states that in the Punjabis this surface is never horizontal in the transverse direction as in Europeans but slopes considerably downwards and medially from the intercondyloid eminence, so that when we look at the head of the tibia from the medial side with the articular surface on a level with the eyes the inter-condyloid eminence is plainly visible as well as a portion of the articular surface; whereas, in a European tibia nothing is seen of either when we look at the bone in this fashion. In the Australian tibiae I did not find this variation. The appearance of the proximal end of the bone when looked at from the medial side was the same as in the European, so far as any obliquity of the articular surface was concerned. This fact, again, is probably to be attributed to the difference in the habitual attitude of the Australian and the Punjabi; in the former the classical position of squatting is but rarely employed. Martin makes the statement that in the primitive human races the medial condyle seems to lie relatively lower and more inclined medially than in the European, owing to which the/

the whole articular surface is directed from the lateral to the medial side. This inclination is especially marked in the Neandertal Homo. I did not find this appearance in any of the Australian bones nor in a group of 40 European tibiae; in fact, in several specimens of both races I observed a slight tilting of the epiphysis in the opposite direction, the medial condyle being elevated instead of depressed.

TORSION OF THE TIBIA.

By this term is meant the twisting of the tibia around a vertical axis. The condition was mentioned by Henle (55) and referred by him to the attitude of the human foot. It was referred to also in the modern European tibia by Poirier (98) in his Traite d'anatomie. In the lower races it was first described by P. and F. Sarasin (93) in connection with the Veddahs of Ceylon. H. Virchow (00) described it also in the Japanese tibia and Rudolf Martin (05) mentioned the appearance in the tibia of the Chinese. Martin believed that the principal change was a rotation of the proximal epiphysis on the diaphysis in such a way that the medial side passed backwards. The condition was first fully investigated by P. le Damany (09). He showed that the torsion of the tibia takes place after birth. In the newly-born the transverse/

transverse axis of the superior articular surface and of the inferior articular surface are parallel to each other. In the course of growth and during the first years of life the inferior transverse axis becomes turned about 20° in such a way as to rotate its lateral end backwards and its medial end forwards. The torsion is due to a rotation of the inferior epiphysis of the tibia around the longitudinal axis, the diaphysis remaining fixed. This rotation takes place at the level of the epiphyseal line, i.e. where diaphysis and epiphysis join. In young subjects the epiphyseal line is represented by the epiphyseal cartilage. The rotation of an epiphysis combined with the growth of the bone produces a spiral form of elongation.

M. le Damany agrees with the view of Henle that the torsion is the result of the attitude of the human foot. It is due in a slight degree to the tendency of our feet to place themselves in the position of abduction when we are lying in the dorsal attitude. But it is mainly due to the habit which we instinctively acquire of turning out the point of the foot in order to improve our base of support. During the first year of life the weight of the foot will cause a continual tendency of the limb to roll outwards. The muscular equilibrium of the limb opposes this. This is the commencement of the torsion./

torsion. The torsion is completed by a second mechanism of which the only cause is muscular action. Two interpretations present themselves and the torsion is probably the result of a combination of the two. 1. To place his foot in abduction man contracts the abductor muscles of his foot and thus makes his foot turn in the tibio-fibular mortise. The medial collateral ligament of the ankle-joint, being fixed, pulls forward the medial malleolus and the whole of the inferior tibial epiphysis follows this movement of lateral rotation. The muscles which produce this abduction of the foot are the extensor digitorum longus and the peroneus longus and brevis. 2. This abduction of the foot, before contact with the ground, is obtained by a somewhat feeble muscular contraction. When the foot is resting on the ground and supporting the weight of the body, abduction is maintained by the adherence between the sole of the foot and the ground. But this attitude is not an attitude of equilibrium for the rotator muscles, nor for the longitudinal muscles of the lower limb. The rotator muscles on the medial side of the thigh, which are the corrector muscles for lateral rotation of the leg, tend to suppress this rotation by bringing back the transverse axis of the knee and the tibio-tarsal axis into the frontal plane. The femur, the superior epiphysis/

epiphysis and the diaphysis of the tibia turn simultaneously. But the inferior epiphysis of the tibia forming a mortise on the talus is maintained by the foot solidly fixed to the ground. It does not rotate. A torsion takes place between the inferior ephphysis and the diaphysis of the tibia.

From the examination of a large number of specimens, le Damany arrived at the following conclusions:-

1. In the human foetus the angle of torsion of the tibia is nil. Torsion commences during the first months of life.

2. In adults the angle of torsion is normally positive. Sometimes it is very large, reaching 40 to 45^{o}; rarely it is nil. Its average value is 20^{o}.

3. By the 5th or 6th year this angle has attained approximately the value which it will have in the adult.

4. The right tibia is more twisted than the left. This difference is evidently in accordance with the functional asymmetry and with the numerical predominance of right-handed people over left-handed.

5. Prehistoric tibiae are twisted like those of our contemporaries and to the same degree. Martin pointed out that the direction of torsion of the tibia is the same as that of the femur and varies in direct relation to it.

Le/

Le Damany was much impressed by the individual variations of this angle in the same series. He mentioned the fact that in the few anthropoid speciment he examined the torsion of the tibia was in the opposite direction to that of man, but the importance of this fact has been pointed out especially by Klaatsch. In the anthropoids the inferior epiphysis is rotated in such a way that the medial end of the transverse axis passes backwards and the lateral end forwards. The angle of torsion is then said to be negative in contrast with the positive angle of man. Klaatsch emphasises the importance of this difference in connection with the origin of man. He maintains that it is very improbable that the positive angle of the Hominidae should have developed from the negative angle of the anthropoids and believes that the positive angle represents the primitive condition which has been preserved in man. Le Damany considered that the negative angle of the anthropoids is dependent on the special functions of the lower limb in these animals and their defective method of walking on the ground. Klaatsch found that although this angle is negative, as a rule, in the higher apes, in the lower monkeys and in the lemur the angle is invariably positive. He observed also that although the angle is usually negative in the anthropoids, in the case of the gorilla a small positive angle is sometimes met with.

Ethnographical position of Australian Tibia as regards degree of Torsion.

Martin gives the following table for the angle of torsion in different races:-

Japanese	+ 14°	La Ferraissie	+ 9 & 10°
Negro	+ 18°	Cro-Magnon	+ 16° 7
French	+ 19°	Spy	+ 23°
New Californian	+ 20°	Neolithic	+ 23°
Paltacalo Indian	+ 20°	Berber	+ 18°
Polynesian	+ 18°	Malay	+ 23°
Altequadornian	+ 19°	Melanesian	+ 23°
French of Middle Ages	+ 21°	Negrito	+ 23°
Patagonian	+ 22°		

The differences between the various human groups are not marked. The Japanese, however, seem to show a lesser degree of torsion than the majority of extra-European races, a fact which probably depends on the position of the foot. The angle of + 23° (Bello) or 25° (Klaatsch) for the tibia of Spy and of + 9° for that of La Ferrassie puts the Homo of Neandertal beside the recent Hominidae and removes him far from the Anthropoids.

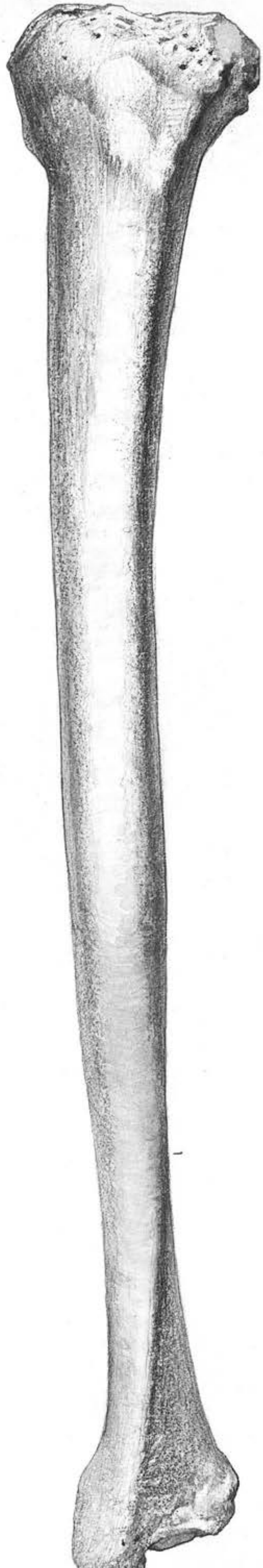
In the Australian bones the average angle of torsion was 17°. This figure is relatively low and comes next to that for the Japanese tibia of the modern races mentioned in the table above. From photographs in the works of Spencer and Gillen referred/

referred to above I was unable to convince myself that the foot of the male Australian aborigine in the standing position was abducted to a less degree than in the modern European. It may be that the habit of sitting with the feet inverted so that the buttocks rest on their medial borders interferes to a certain extent with the torsion of the tibia. Klaatsch states that the Australian females stand with their feet practically straight in the sagittal direction. In a few specimens the angle of torsion was nil. The highest angle obtained was 55^{o}5. This extreme degree of torsion is seen in the specimen illustrated in Plate VI. It will be noticed the surface of the distal epiphysis which is usually posterior is actually medial in this bone.

Le Damany made the observation that the angle of torsion was usually greater in the right tibia than in the left. In the present series I found the reverse condition. In 86 pairs of tibiae the left angle was the greater in 70 cases, the right in 15, and the angles were equal in only one pair of bones. The difference in the size of the angle on the two sides was so striking that I thought it of interest to calculate the average angle on each side in the 86 pairs; the average angle of torsion of the right tibia was $12^{o}6$, that of the left was $21^{o}6$, which is quite a marked difference. The probability seems to/

Plate VI.

Anterior and medial views of a specimen which showed an extra-ordinary degree of torsion as well as marked retroflexion. In the medial view the groove for the tendon of the tibialis posterior is seen on what is normally the posterior aspect of the malleolus; in this case it is medial.

to be that the difference in the angle, as suggested by le Damany, has to do with the asymmetry in function of the two sides of the body; but, if the Australians are mainly right-handed, it is not clear why the relative size of the angle on the two sides should be the opposite of that in the European individual.

In the few young bones at my disposal, I was able to confirm the observation of le Damany, that the angle of torsion is well-marked at an early age.

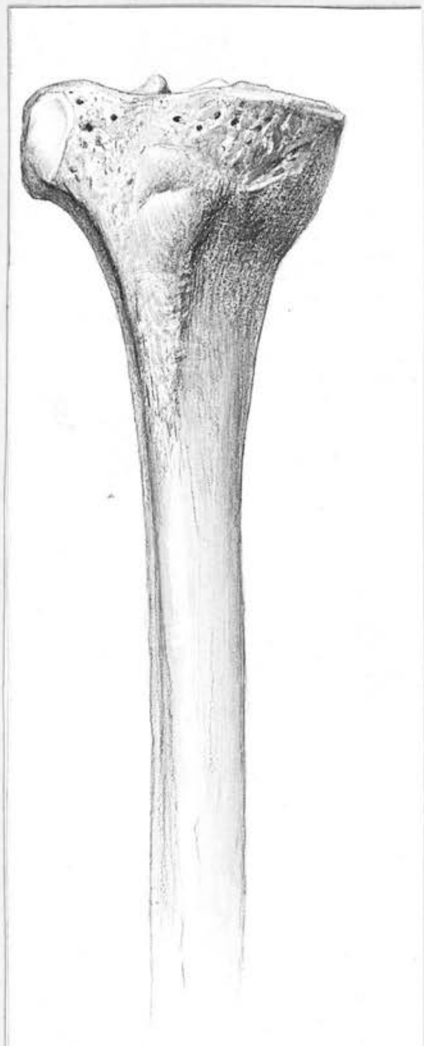
It may be pointed out in conclusion that, owing to the great individual variation which exists in all groups as regards the angle of torsion, this feature is not very satisfactory from the point of view of racial diagnosis.

IMPRESSION ON ANTERIOR ASPECT OF LATERAL CONDYLE.

While measuring the Australian bones I was struck by an appearance on the anterior aspect of the lateral condyle which I had not previously noticed in European bones. This consisted of an ovoid or circular impression about 7 to 10 m.m. in diameter, flattened or slightly excavated, with a smooth regular surface of dense compact bone. The area had very much the same appearance as an articular surface. The appearance is illustrated in Plates II and VII . This facet or impression was very constantly present; in the

Plate VII.

The proximal extremity of a tibia presenting a well-marked facet on the anterior aspect of the lateral condyle.



236 specimens it was absent or poorly marked in only 43 cases. On examining a number of modern European tibiae I found it also occasionally present. To ascertain its relative frequency I inspected the series of 118 tibiae and found it distinctly present in 20 cases; in other 8 bones it was present but feebly marked.

To explain this appearance in the Australian bones there are two possibilities which present themselves. Is it an acquired impression produced by pressure in the habitual kneeling attitudes which are so frequently adopted by the aborigines or is it an exaggeration of the normal impression produced by the attachment of an anatomical structure? If we endeavour to reproduce the common attitude with the knees acutely flexed and the feet inverted so that the tuberosities of the ischia rest on their medial borders, we find that, although the weight of the body is transferred very largely to the tuberosity of the tibia, there is a considerable amount of pressure on that part of the lateral condyle on which the impression in question is found. Of the anatomical structures attached to the tibia in this region the ilio-tibial tract suggests itself as being the most likely to produce such an impression. A somewhat similar smooth appearance is given to the bone by the attachment of the ligamentum patellae to the distal/

distal part of the tuberosity of the tibia and by the insertion of the tibialis anterior to the medial cuneiform. The description of the attachment of the ilio-tibial tract to the tibia varies to a certain extent in different writers. In an article, "On some minor markings on bones", in which he gives a most minute description of the various appearances produced by the structures attached to the proximal end of the tibia, J. Ernest Frazer (06) does not mention any impression as produced by the attachment of the ilio-tibial tract. He indicates in an illustration a horizontal line on the antero-lateral aspect of the lateral condyle as the "insertion of the deep fascia and the biceps expansion". E.B. Jamieson (13) describes it as a "well-marked ridge anterior to the fibular facet". Peter Thompson (15) in Morris's Treatise on Anatomy describes it simply as a ridge at the junction of the anterior and lateral surfaces of the condyle. Arthur Thomson (13) in Cunningham's Textbook of Anatomy states with reference to the lateral condyle that antero-laterally the imprint caused by the attachment of the ilio-tibial tract is often quite distinct. Although this description does not convey the idea of an appearance like that described in the Australian bones, the illustration which accompanies the text shows in a similar situation to the facet mentioned an elevated impression described/

described as the attachment of the ilio-tibial tract (see Fig.28)

In order to verify the attachment of the ilio-tibial tract to this part of the condyle I dissected the structure in 6 specimens. I found that the attachment of the band extended forwards from the tibio-fibular articulation to the anterior aspect of the lateral condyle. The tract could be separated from the subjacent capsule of the knee-joint, but the two structures were closely adherent towards their attachment to the tibia. The anterior portion of the attachment of the ilio-tibial tract extended distally on the anterior aspect of the condyle and was attached to the area under discussion. This anterior portion constituted the main attachment of the tract and received quite an extensive insertion to almost the whole of the anterior aspect of the lateral condyle.

Inspection of the lateral condyle in a number of European tibiae showed the presence of a horizontal ridge, 2-3 c.m. in length, situated about 5 - 10 m.m. below the articular margin and extending forwards from the upper margin of the fibular facet. This ridge indicates the combined attachment of the posterior part of the ilio-tibial tract and the lateral portion of the capsule of the knee-joint. At its anterior end the ridge becomes continuous with the

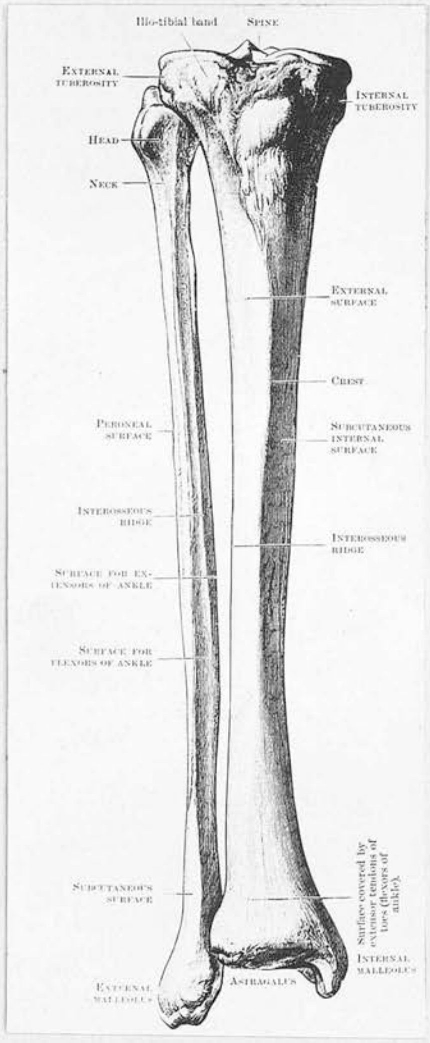


Fig. 28.

Reproduction of illustration from Cunningham's Textbook of Anatomy, showing position indicated by Thomson as attachment of ilio-tibial tract.

the area of the anterior surface of the lateral condyle to which the stronger portion of the ilio-tibial tract is attached. In the European bones this area usually presented the appearance of a triangular flat surface bounded in front by a faint elevation and below by the ridge indicating the line of attachment of the deep fascia of the anterior tibio-fibular compartment of the leg. The surface of the bone in this region was rough and similar in appearance to that of the neighbouring part of the bone. Occasionally the anterior boundary of this area became raised up in the form of a more or less vertical ridge, which is the appearance referred to by some authors, but this ridge indicates only a small part of the attachment of the ilio-tibial tract. In a few specimens, as mentioned above, there was the presence of a smooth, flat or slightly concave facet similar to that described in the Australian tibiae.

The evidence would seem to show that the impression on the anterior aspect of the lateral condyle of the Australian tibiae is produced by the attachment of the ilio-tibial tract. The examination of specimens of pathological conditions such as club-foot reveals the fact that, although adventitious facets are of common occurrence where two bony surfaces are in contact, they practically never result from pressure applied to a bone through the skin. I examined the/

the skeleton of the foot of a case of talipes equinovarus in a man aet. 50 in the Museum of the Royal College of Surgeons. This individual had walked for the greater part of his life on the lateral border of the foot, yet the bones on the lateral side showed no sign of the development of smooth pressure facets such as are met with in the neighbourhood of joints or such as the one under discussion. The lateral border of the base of the 5th metatarsal, it is true, showed a slight rounded elevation, but the surface of this was quite rough and like the adjacent bone. From the attachments of the ilio-tibial tract, from the appearances produced by similar attachments in other bones, and from the occurrence of the same impression in the bones of Europeans we may conclude that this structure is the cause of the facet described in the Australian tibiae. Since the impression is much more distinct in the Australian bones we should expect to find a greater strain on the ilio-tibial tract in the aborigines. We may presume that such an increased strain will be produced by the same energetic conditions of life which cause platycnemia - hunting, etc.

SOME MINOR APPEARANCES ON THE EPIPHYSES.

The dimensions of the epiphyses have already been considered. It has been shown that the epiphyses in the/

the Australian tibiae are small and narrow, especially when considered in relation to the great length of the bones. The increased convexity of the articular surface of the lateral condyle and the presence of additional facets for the talus on the anterior border of the distal epiphysis have also been discussed.

Klaatsch, in particular, in his valuable researches on some of the prehistoric forms, has referred to the possible importance of the minor features of the epiphyses. Of the impressions produced by the attachments of ligaments to the proximal epiphysis, I found that for the ligamentum cruciatum posterius rather different in appearance to the impression in European tibiae; as a rule, it was considerably narrower and deeper in the Australian specimens. The tuberosity presented usually a larger and better marked impression for the attachment of the ligamentum patellae than is found in European bones. In cases of marked retroversion, as has been noted by Manouvrier, the anterior surface of the epiphysis is somewhat elongated.

Klaatsch points out the existence on the posterior aspect of the epiphysis of a depression which he terms the Impressio Subcondyloidea Lateralis. It is situated immediately below the projecting posterior portion of the lateral condyle, medial to the fibular facet. In the Spy tibia it is particularly well-marked/

well-marked and forms a broad, shallow, almost circular depression. In European tibiae I found this appearance usually absent, although in a few cases there was presented a slight excavation just below the lateral condyle. In the Australian specimens it was also rarely present; when it occurred it took the form of a circular fossa, considerably smaller than in the Spy tibia and situated closer up to the posterior margin of the condyle. The impression on the medial condyle for the insertion of the semimembranosus has been dignified by Klaatsch with the name of the Fossa Subcondyloidea Medialis. He points out that the ridge which forms the medial boundary of the planum popliteum of the tibia commences just below. In the Spy tibia the fossa is rather rounded in shape and lies posterior to the transverse axis of the epiphysis; the articular surface of the medial condyle shows a very distinct extension towards the position of the depression. In the tibia of Homo Aurignacensis the fossa takes very much the same appearance as in the modern Eueopean tibia; it forms a transverse furrow parallel to the articular margin and is bounded below by a well-marked ridge. The elevation running downwards from it to form the medial boundary of the planum popliteum is smaller and does not extend so far distally as in the Spy tibia. In the Australian tibiae the fossa had practically the same shape and position/

position as in the European tibia, forming a horizontal groove on the postero-medial aspect of the proximal epiphysis. The ridge which bounds the planum popliteum medially was very variable in size and shape; in some cases it took the form of a long, narrow, distinctly-marked ridge, in others it was flat and rounded and only extended downwards for a short distance, while in many cases it was absent altogether. It would seem that this feature is not likely to be of much value in racial diagnosis. The extension of the articular surface, noted in the Spy tibia, towards the position of the fossa, did not occur in either the Australian or the European specimens examined.

The intercondyloid eminence was well developed in the Australian tibia. As has been mentioned previously its average height was 6 m.m. while the average height in European tibiae was 5.1 m.m.

Klaatsch notes an appearance in the Spy tibia which may be of considerable importance, namely, a backward displacement of the whole proximal epiphysis, so that the condyles overhang the posterior surface of the bone in a very marked fashion and the appearance of a transverse groove is produced just below the condyles. He points out that if we imagine this groove to be obliterated and the epiphysis displaced forwards, we get an appearance like that of the modern European/

European tibia; whereas, if we imagine the groove to be displaced distally we get the condition of retroflexion. He implies that the European tibia would indicate a development from the Spy tibia in one direction and that of races with retroflexion development in another. This appearance of a backward displacement of the proximal epiphysis was very distinct in many of the Australian tibiae. It never occurred in a retroflexed bone but was usually associated with a considerable degree of retroversion. The fact of its occurrence in a race which also presents the change of retroflexion would throw a doubt on its being a racial feature and makes it more likely to be due to physiological or mechanical causes.

The groove for the tendon of the popliteus and the facet for the proximal end of the fibula did not present any distinctive features; as in European bones they were well-marked in some cases and poorly-marked or absent in others.

In the case of the distal epiphysis, Martin (94) referred to certain variations in appearance in the tibia of the natives of Tierra del Fuego. He found the distal epiphysis more flattened from before backwards then in Europeans; the anterior aspect was slightly concave while the posterior surface was strikingly flat with no indication of a groove for the/

the tendon of the tibialis posterior. In the Australian tibia none of these variations were present. The uniformly slender dimensions of the distal epiphysis have already been mentioned, but there was no relative flattening from before backwards; the anterior aspect of the epiphysis showed the same convexity as in the European and the groove for the tendon of the tibialis posterior was frequently well-marked. Klaatsch (10) describes a feature on the distal epiphysis which he calls the Praefibular Process. This consists of a marked projection of the anterior border of the incisura fibularis in a somewhat peg-shaped manner. The articular surface extends on to the lateral aspect of the projection, the area on this being separated from the remainder by a definite border. Klaatsch found the process especially well marked in the Australian tibia. I examined a series of 40 European tibiae and found it present in 4 instances. In the Australian tibiae it was of common occurrence, with a very definite extension of the articular surface on to its lateral aspect. It may be noted that such a projection will add to the stability of the distal tibio-fibular articulation and we should expect to find it more frequently in those races who find it necessary to hunt and run in uneven country, i.e. those races in which platycnemia is/

is of common occurrence.

Klaatsch refers to the shape of the distal epiphysis in contrasting the Spy tibia with that of Homo Aurignacensis. In the former he found it considerably broader and more massive than in the latter; the medial malleolus, also, in the former was broad and somewhat rounded while in the latter it was shorter and more conical and occupied a slightly oblique position. In the Australian tibiae there was a striking resemblance between the shape of the malleolus and that of Homo Aurignacensis; it had a distinctly conical outline, more so than in the European tibia; it was shorter than that of Spy, and was quite commonly slightly oblique in position. It has already been mentioned that the average length of the malleolus in the Australian tibia is considerably greater than in the European tibia - 13.8 m.m. and 7.6 m.m. being the respective measurements. Another point which I observed in connection with the medial malleolus in the Australian tibiae was the frequent occurrence of an extension of the articular surface on to the anterior aspect, this part of the malleolus being somewhat bevelled. This condition would favour the upward passage of the broad anterior part of the talus and is probably to be attributed to habitual extreme dorsiflexion at the ankle joint, and possibly also to the inversion of the foot in the position

in/

in which the individual sits with the feet tucked under the buttocks.

MINOR POINTS IN CONNECTION WITH THE DIAPHYSIS.

It has been mentioned that the anterior border of the European tibia in its proximal portion is usually somewhat concave. In the Australian tibia the anterior border in its proximal two-thirds is nearly always convex. In only 6 cases was it concave or straight. The average height of the curvature as measured from the chord to the point of maximum convexity was 4 m.m. The Curvature Index which is calculated from the formula, $\frac{\text{Height of curvature} \times 100}{\text{Chord of curve}}$, was 2.02.

The average circumference at the middle of the bone was 81 m.m., at the nutrient foramen 89 m.m., and at the most slender point 70 m.m. In 12 European tibiae the average circumference at the middle was 84.5 m.m., at the nutrient foramen 96.5 m.m., and at the most slender point 75.6 m.m. This comparison illustrates again the relatively slender conformation of the Australian tibia.

Klaatsch mentions in the left tibia of Homo Aurignacensis a curvature of the diaphysis with the concavity directed laterally. He thought at first that this bend was probably pathological but discovered it later to be of common occurrence and on both sides in/

in the Orang, which he considers the skeleton of Homo Aurignacensis to resemble. This change was met with in the Australian tibiae to a slight degree in 3 specimens but in as many cases the opposite variety of curvature was present with the concavity directed medially, so that it is doubtful if the former change has any special significance in this race.

COMPARISON OF THE AUSTRALIAN TIBIA WITH PRE-HISTORIC FORMS.

Duckworth in "Morphology and Anthropology" makes the following statement, "While there is little doubt that simian features are not all concentrated in any single race (this was pointed out by Turner some years ago) yet there can be no doubt that the aborigines of Australia and Tasmania have (up to the present) furnished the examples of the greatest concentration of ape-like characters. But we must not therefore conclude that these aborigines present us with a fac-simile of a human ancestor; for these very abroigines are themselves remarkably specialised in adaptation to their surroundings". So far as the tibia is concerned, we may conclude from what has been said in the present article that none of the special features presented by this bone can be regarded as simian. In view of the great length of the tibia, however, it is probable that the tibio-femoral index/

index would have been simian in character.

Klaatsch in the Zeitschrift für Ethnologie (1910) holds that the descent of man took place along the lines indicated in Fig.

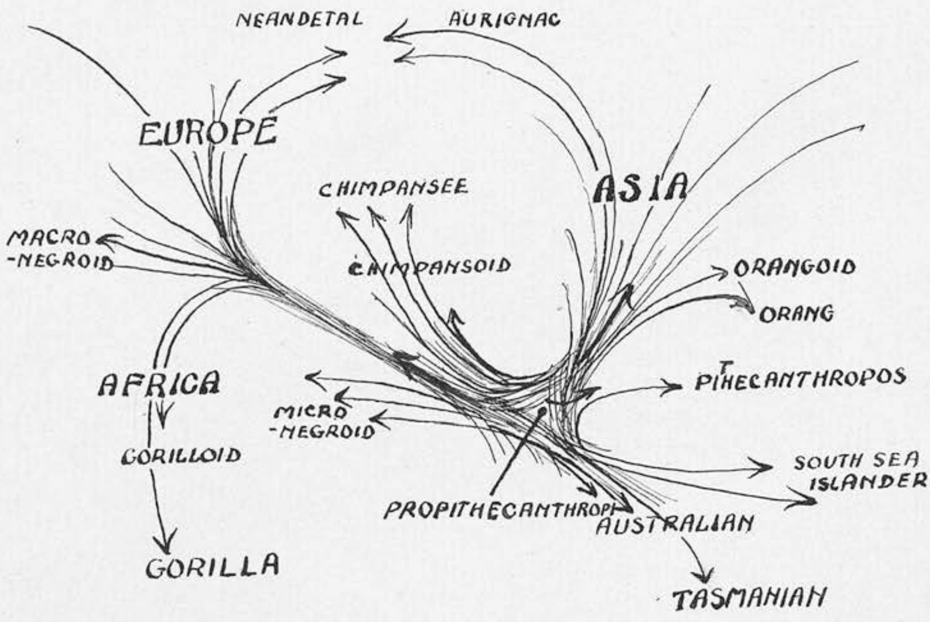


Fig.31.

He maintains that Pithecanthropus erectus and the Simiidae are not the precursors of the Hominidae. He postulates the existence of an ancestral series parallel to that which has culminated (according to Klaatsch) in the Simiidae and through which the Hominidae are connected with an ancestor which they share in common with the Simiidae, the hypothetical Propithecanthropus/

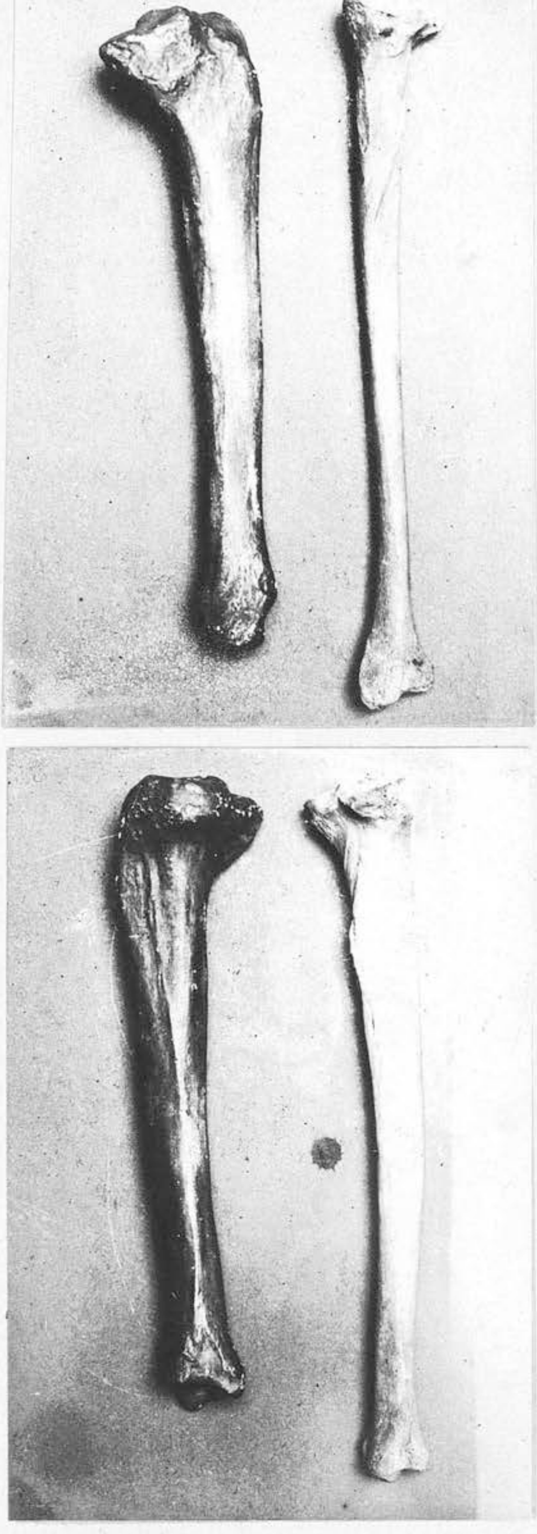


Fig. 29.

Medial and lateral views of the Spy cast compared with an Australian tibia. The differences in appearance are very striking. Note especially the greater massiveness of the Spy tibia and the huge epiphyses.

Propithecanthropus of the diagram.

In support of the view of descent indicated in Fig.31 he traces a close resemblance between the Spy skeleton and that of the Gorilla, while he maintains that the skeleton of Homo Aurignacensis differs widely from that of the Gorilla but presents a close resemblance in many particulars to that of the Orang. He considers ths skeleton of the Australian aborigine to be much more closely related to the Aurignacensis form than to that of Spy.

It will be of interest to see how far the results of the present examination confirm the resemblance to Homo Aurignacensis with regard to the tibia. If we look at the Australian tibia as a whole, the similarity in its general conformation to that of Aurignac is very striking, as, indeed is the contrast to that of Spy (see Figs.29 and 30). I give here a comparative table of the main dimensions of the tibia of Aurignac, the Australian, and Spy.

	Homo Aurignacensis	Australian	Spy.
Greatest length	380 m.m.	386 m.m.	336
Proximal epiphysis	72 "	69 "	82
Distal "	43 "	45 "	58
Platycnemia			
Sagittal diameter	36	33	44
Transverse "	21	22	35

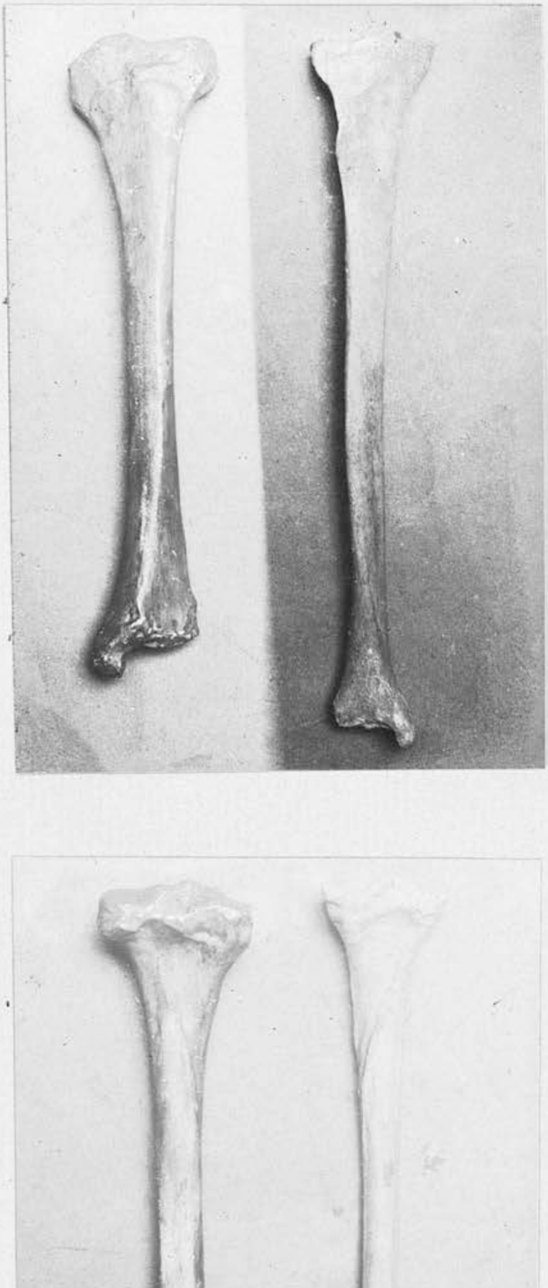


Fig. 30.

Anterior and posterior views of the same. In the posterior view of the Spy tibia the position of the "Impressio subcondyloidae lateralis is seen.

The difference between the short massive tibia of Spy with its broad epiphyses and the long slender tibia with narrow epiphyses of the other two forms is sufficiently obvious. By superimposing tracings of the different varieties Klaatsch makes the difference in the dimensions of the epiphyses very apparent. He states also that the intercondyloid eminence in the Aurignac-Orang type of tibia is less accentuated than in the Spy-Gorilla form, but I found the eminence extremely well-developed in the Australian tibia, slightly longer, in fact, than in the European. The impression for the attachment of the ligamentum cruciatum posterius in the Aurignac tibia, and also in the Australian, is relatively deep while in the Spy tibia it is broad and comparatively shallow. Klaatsch traces a distinction, also, in the shape and situation of the Impressio subcondyloidea lateralis and the Fossa subcondyloidea medialis in the two prehistoric types. I found that both these features in the Australian tibia conformed to the appearances in the Aurignac specimens; the lateral impression when present was relatively narrow and very close up to the posterior margin of the lateral condyle, while in Spy it is broad and situated a little more distally; the medial fossa took the form of a well-marked horizontal groove on the postero-medial aspect of the/

the condyle, whereas in Spy it is a more or less rounded depression situated well behind the transverse axis of the epiphysis. In the shape of the medial malleolus the Australian tibia presents a close resemblance to the tibia of Homo Aurignacensis, this process being relatively short, slender, and conical when compared with the massive rounded process of the Spy tibia.

We can confirm, therefore, the general similarity between the Australian tibia and that of Homo Aurignacensis and the marked contrast which it forms with the tibia of Spy, indicating, most likely, a closer relationship between the first two varieties. But it is impossible to go further than this with regard to Klaasch's view of the relationship of the primitive forms. A great deal more palaeontological evidence will be required before it can be proved that the Hominidae are derived from an ancestral series parallel to but not springing from the Simiidae. It seems just as probable, in the meantime, that the Simiidae represent the preservation, with considerable secondary changes, of a stage in the evolution of the Hominidae.

SUMMARY AND CONCLUSIONS.

Length of the Tibia.

The Australian tibia is very long, not only in relation to the body height but also when compared with the tibia of other races. This feature is especially striking when considered in relation to the small size of the epiphyses. The average length in the present series as measured from the articular surface of the lateral condyle to the tip of the medial malleolus was 380 m.m. Variations in length are considerable - from 316 m.m. to 446 m.m. in the present series. The intercondyloid eminence is well-developed and is slightly longer than in European tibiae. The medial malleolus is longer than in European tibiae but considerably shorter than that of the tibia of Spy. The tibia of the two sides are nearly always asymmetrical as regards their length; they were equal in the present series in only 7.6% of cases; the right tibia being slightly more frequently the longer of the two.

The index of massiveness or relation of thickness to length is lower in the Australian tibia than in that of any other race in which it has been estimated.

Dimensions/

Dimensions of the Epiphyses.

The measurements of the epiphyses are of the greatest importance from the point of view of racial diagnosis. The epiphyses in the Australian tibia are very small and this appearance is all the more striking in view of the great length of the bone. The diameters in both the transverse and the sagittal directions are less than in almost any other race in which they have been measured.

Platycnemia.

The average cnemic index for the series was 65.2 so that the Australian tibia occupies an intermediate position when its index is compared with that of other races. Many of the bones showed well-marked platycnemia, according to the definition of Manouvrier.

The examination of the platycnemic specimens confirmed in every respect the view that the essential cause of this change is a hypertrophy of the tibialis posterior. Platycnemic tibiae in European races present the same alterations as in the Australian bones; the cause of the condition is probably the same in both cases.

The size of the impression for the attachment of the tibialis anterior shows no difference in eurycnemic and in platycnemic bones; that for the tibialis posterior, on the other hand shows a marked increase/

increase in both length and breadth in platycnemic specimens. Retroversion of the head of the tibia is not a necessary concomitant of platycnemia.

Outline of the Tibia at the Level of the Nutrient Foramen.

The most common appearance of a transverse section of the Australian tibia is that in which the posterior aspect is subdivided into a postero-lateral area for the tibialis posterior and a postero-medial area for the flexor digitorum longus. A rare form of platycnemic bone in which the surface for the tibialis posterior lies in the same plane as that for the tibialis anterior is comparatively common.

Retroversion and Retroflexion.

The methods previously employed in estimating the angle of retroversion are unsatisfactory. The best means of indicating the morphological axis of the tibia is to fix a long steel needle on the lateral surface, when the tangent to the articular surface of the medial condyle in the sagittal plane is parallel to the surface below, estimating by the eye the line of the axis of the diaphysis.

In the Australian tibia the average angle of inclination is 13°, which is very high in comparison with other modern races. Retroversion being present in/

in the infant, this change is maintained by the habitual adoption of attitudes producing extreme flexion at the knee joint. A consideration of the attitudes adopted by the Australian aborigines shows that this is not necessarily the attitude of squatting. Retroversion is a fairly common condition in European tibiae. It may very well be dependent on occupations which involve an extreme degree of flexion at the knee joint.

Although retroversion is commonly associated with platycnemia in the lower races, the two conditions are due to different causes, the former being dependent on the habitual attitude of the individual and the latter on a hypertrophy of the tibialis posterior.

Retroflexion is not of frequent occurrence in the Australian tibia. The significance of this change is not yet decided. The bones in which it is present are usually strong and well-formed so that it is probably not due simply to yielding of the bone to forces tending to bend it in the sagittal direction. The type of curvature does not correspond to that observed in pathological conditions in which the bones are softened and bend under the weight of the body.

Convexity of the Articular Surface of the Lateral Condyle.

The average degree of this change in the Australian tibia corresponds to 2.3 of Thomson's scale. Like

Like retroversion it is due to habitual acute flexion of the knee joint in the common attitudes of rest, which are not necessarily squatting attitudes. A small degree of convexity is not compensated for by a greater degree of retroversion or retroflexion. The relationship to platycnemia is like that of retroversion, since the two conditions are due to different causes.

Articular Facets on the Anterior Border of the Distal Epiphysis.

The lateral facet is almost constantly present in the Australian tibia; the medial rarely occurs. They are due to habitual extreme dorsiflexion at the ankle joint in the postures of rest.

In the European tibia the lateral facet is of fairly common occurrence; it is possibly due to the same cause, the dorsiflexion being dependent on occupation.

Torsion of the Tibia.

In the newly-born the transverse axes of the two epiphyses are parallel to each other. Torsion of the bone commences at a very early age. In the torsion of man the transverse axis of the distal epiphysis is rotated in such a way that its medial end passes forwards; in the anthropoids the torsion takes place in the opposite direction.

In/

In the Australian tibia the average angle of torsion is 17°, which is a relatively low figure. The angle is usually much greater in the left tibia than in the right so far as Australians are concerned.

Impression on the Anterior Aspect of the Lateral Condyle.

The majority of Australian tibiae present a well-marked circular or ovoid, smooth facet, flattened or slightly concave, on the anterior aspect of the lateral condyle. It is occasionally, but much less frequently, present on the European tibia. It is produced by the attachment of the anterior portion of the Tractus Ilio-tibialis.

Minor Features of the Epiphyses.

The proximal epiphysis of the Australian tibia usually lies in much the same relation to the axis of the diaphysis as in the European tibia, but occasionally it presents a distinct backward displacement similar to that seen in the Spy tibia. The articular surface of the medial condyle never presents an obliquity in the downward and medial direction. The impression for the attachment of the ligamentum cruciatum posterius is narrower and deeper than in the European tibia. The Impressio subcondyloidea lateralis of Klaatsch is only occasionally present. The groove for the insertion of the semimembranosus has/

has the same appearance as in the European tibia. The elevation which runs distally from this groove and forms the medial boundary of the planum popliteum is very variable. The Praefibular Process of Klaatsch is commonly present. The inferior articular surface occasionally extends on to the anterior aspect of the malleolus.

The anterior border of the Australian tibia is usually distinctly convex forwards.

Comparison with Prehistoric Forms.

The Australian tibia presents a very close resemblance in its general conformation to the tibia of Homo Aurignacensis and forms a marked contrast to the tibia of Spy. The minor features of the epiphyses also exhibit a general similarity to those of the former type.

To sum up, it may be said that the features which are especially striking in the Australian tibia are its great length, the small size of the epiphyses, the marked degree of retroversion, the almost constant presence of facets on the anterior border of the distal epiphyses, and the low degree of torsion; the degree of platycnemia and of convexity of the articular surface of the lateral condyle are only moderate.

In/

In conclusion, I wish to express my great indebtedness to Professor Robinson. It was at his suggestion that this research was undertaken, and his helpful advice and stimulating interest throughout have greatly diminished the tedium of the work.

To Mr J. T. Murray I am indebted for the drawings which illustrate this article and which exhibit his well-known ability. The photographs are the work of Mr William Watson of the College of Physicians Laboratory and of Mr Alec Turner of the University Anatomy Department, and my thanks are due to them for their care and trouble.

To Miss Joyce Alexander I have to express my thanks for most of the reproductions of diagrams in the article; the sources from which the diagrams are taken are acknowledged in the text.

I am indebted also to the Earl of Moray Research Fund for a grant towards the expenses of the work.

BIBLIOGRAPHY.

Aitken, D.M. 1905. Notes on the Variations of the Tibia and Astragalus, Journal of Anatomy and Physiology. London. Vol.39. P. 489.

Anthony. 1903. Introduction à l'étude expérimentale de la morphogenie. Bulletins et memoires de la Société d'Anthropologie de Paris.

Anthony et Rivet. 1908. Etude anthropologique des races précolombiennes de la republique de l'Equateur. Bulletins et memoires de la Société d'Anthropologie de Paris.

Baetz. 1901. Verh. der Berliner Ges. fur Anthr. P.203.

Bello, Rodriquez Y. 1909. Le fémur et le tibia chez l'homme et les anthropoides. Thèse Paris.

Brachet, A. 1900. Sur l'incurvation en arrière de la tête du tibia chez le foetus humain et le nouveau-né. Ann. Soc. Med-chir. Liège. Ann. 39. P.240.

Broca. 1868. Sur les crânes et ossements des Eyzies. Bulletins de la Société d'Anthropologie Sér.2. T.3. P.350. Paris.

Busk. 1869-70. On the discovery of platycnemic men in Denbighshire. Journal of the Ethnological Society. New series. Vol.2. P.440.

Charles, H.C.R. 1893. The Influence of Function as Exemplified in the Morphology of the Lower Extremity of the Punjabi. Journal of Anatomy and Physiology. London. Vol.28, pp.1 & 271.

Collignon. 1880. Descriptions des ossements fossiles humains. Revue d'Anthropologie. Paris. Vol.9.

Cunningham. 1913. Textbook of Anatomy. London.

Danielli. Enciclopedia Medica Italiana. Fasc.235. P. 1020.

Derry, D.E. 1907. Notes on Predynastic Egyptian Tibiae. Journal of Anatomy and Physiology. London. Vol.41. P. 123.

Duckworth, W.L.H. 1904. Morphology and Anthropology. Cambridge.

Fick. 1857. Uber die Ursuchen der Knochenformen experimental Untersuchung. Gottingen.
1858. Neue Untersuchunger uber-die Ursuchen der Knockenformen. Marburg.

Fraipont, J. 1887. La race humaine de Néanderthal. Archiv. de Biologie Gand. Tome 7. Fasc. 3. pp. 587 - 757.
1888. Le tibia dans la race du Néanderthal. Revue d'Anthropologie. Paris. Sér 3. T.3.P.145.

Frazer, J.E. 1906. Some Minor Markings on Bones. Journal of Anatomy and Physiology. 3rd series. Vol. I. P.267.

Guérin. Essai de physiologie générale.

Hartman. 1886. Les singes anthropoides et leur organisation comparé à celle de l'homme. Bibl. scient. P. 106.

Henle. 1855. Handbuch der Systematischen Anatomie des Menschen.Braunsweig.

Hirsch, H.H. 1895. Die mechanische Bedeutung der Schienbeinform Berlin.

Hovelacque et Hervé. 1887. Précis d'Anthropologie. Paris.

Hrdlicka, A. 1899. Study of the normal tibia. Proceedings of the 11th Annual Session of the Association of American Anatomists. P.61.
Amer. Anthrop. Vol.2. P.307.

Hueter, C. 1862. Anatomische Studien an den Extremitatengelenken Neugeborener und Erwachener. Virchow's Archiv. Bd. 25 and Bd. 26.
1863. Das Kniegelenk, etc. Archiv fur Path. Anat. Berlin.

Hultkrantz, J.V. 1900. Zur Osteologie der Ona- and Yahgan- Indianer des Feuerlandes. Wissenschaftliche Ergebnisse der swedischen Expedition nach den Magellanslandern 1895-97 unter Leitung von O. Nordenskjoeld. Stockholm.

Issel, A. 1878. Nuove ricerche sulle caverne ossifere della Liguria. Accad dei Lincei. Roma.

Jamieson, E.B. 1913. A Companion to Manuals of Practical Anatomy, London.

Khuff. 1881. De la platycnemie dans les races humaines. Revue d'Anthropologie. Paris. Sér 2. T.4. P.255.

Klaatsch, H. 1899. Die fossilen Knochenreste des Menschen und ihre Bedeutung far das Abstammungs-Problem. Ergebnisse der Anatomie und Entwickelungsgeschichte. Merkel und Bonnet. Bd. 9.
1900. Die wichtigsten Variationen am Skelet der freien unteren Extremitat. Ergebnisse der Anatomie und Entwickelungsgeschichte. Merkel und Bonnet. Bd. 10.
1901. Das Gliedmassenskelet des Neanderthalmenschen. Anat. Anz. Bd.19. Ergz. H. P.121.
1910. Die Aurignac-Rasse und ihre Stellung im Stammbaum der Menscheit. Zeitschrift fur Ethnologie. Heft 3 and 4.

Klaatsch, H. & O. Hauser. 1910. Homo Aurignacensis Hauseri. Prähistor. Zeitschr. Bd.I. Heft 3 & 4.

Koganei. 1894. Kurze Mitteilung uber Untersuschangen von Aino-skeleten. Archiv. fur Anthrop. Bd.22

Lane, Sir Arbuthnot. 1888. Effect of strain on Bones, Muscles, and Ligaments. British Medical Journal. Etc.

MacRitchie, D. 1893. Platycnemia in the British Isles. Journal of the Anthropological Institute. London. Vol. 22. P.399.

Manouvrier, L. 1887. La platycnemie chez l'homme et chez les singes. Bulletins de la Société d'Anthropologie de Paris T.10. Sér.3. P.128.
1888. Memoires sur la platycnemie chez l'homme et chez les anthropoides. Memoires et Bulletins de la Société d'Anthropologie de Paris. Sér. 2. T.3. P.469
1893. Etude sur la retroversion de la tête du tibia et l'attitude humaine à l'époque quaternaine. Memoires et Bulletins de la Société d'Anthropologie de Paris. Sér. 2. T.4. P.219.

Marey. 1887. Recherches sur la Morphologie des muscles. Comptesrendus de l'académie des sciences. Paris. Des lois de la morphogénie chez les animaux.

Martin, Rudolf. 1894. Zur physischen Anthropologie der Fenerlander. Archiv fur Anthropologie Bd.27. P.155-217.
1914. Lehrbuch der Anthropologie. Jena.

Morris. 1915. Treatise on Anatomy, 5th Ed.

Nadaillac. 1880. L'Amerique prehistorique.

Papillault. 1899. Mode de croissance chez un géant. Bull. de la Société d'Anthropologie.
1901. Les modifications fonctionelles du squelette. Revue de l'Ecole d'Anthropologie.

Regnault, F. 1898. Forme des surfaces articulaires des membres inférieurs. Bulletins de la Société d'Anthropologie de Paris. Sér. 4. T.9. P.535.
1901. Role des muscles dans la morphogenie osseuse. Bulletins et Memoires de la Société d'Anthropologie de Paris.

Retzius, G. 1900. Ueber die Aufrichtung des foetal retrovertierten Kopfes der Tibia beim Menschen. Zeitschrift fur Morphologie und Anthropologie. Bd.2. P.166.

Sarasin, P. and F. 1893. Die Weddas von Ceylon und die sie umgebenden Volkerschaften. Wiesbaden.

Schaafhausen. 1882. Archiv fur Anthropologie Vol.14. Corresp. Bl. der deutschen Gesellschaft.

Short. North America of Antiquity.

Spencer & Gillen. 1899. Native Tribes of Central Australia. London.
1904. Northern Tribes of Central Australia. London.

Spencer. 1914. Native Tribes of the Northern Territory of Australia. London.

Thomson, A. 1889. The Influence of Posture on the Form of the Articular Surfaces of the Tibia and Astragalus. Journal of Anatomy and Physiology. Vol. 23. P.616.
1890. Additional note on the same. Journ. Anat. Physiol. Vol. 24. P.210.

Topinard. 1885. Eléments d'Anthropologie Generale. pp.1040-1041.

Turner. Sir W. 1889. Challenger Reports, part 47.

Vallois, M.H. 1912. Considération sur la forme de la section transversale du tibia. Bulletins et Memoires de la Société d'Anthropologie de Paris. Sér.6. T.3. P.248.

Virchow, Hans. 1900. Das Knie japanischer Hocker. Verh. Berl. Ges. Anthrop. P.385.

Virchow, Rud. 1880. Ausserungen uber Platyknemie. Zeitschrift fur Ethnologie. Berlin.
1886. Prahistorische anthropologische verhaltnisse in Pommern.

Wetzel, G. 1911. Apparate und Erlauterungen zur perigraphischen Technik. Zeitschrift fur Morphologie und Anthropologie. Bd.13. pp.541-598.

Wolff. 1870. Uber die innere Architectur der Knochen u. s. w. Virchow's Archiv.

Wyman. 1873. Report Peabody Museum.

TABLE OF MEASUREMENTS DESCRIBED UNDER

"TECHNIQUE"

The numbers at the head of the various columns correspond to the numbers of the measurements described from p. 3 to p. 9.

(1) A

Number of bone.	Whole length of Tibia.	Greatest length of Tibia.	Length of Tibia.	Condylo astragaloid length.	Joint surfaces distance.	Greatest breadth of Proximal Epiphysis.	Greatest Sagittal Diameter at Tuberosity.	Smallest Transverse Diameter at Tuberosity.	Greatest Breadth of Distal Epiphysis.
	1	1a	1b	2	2a	3	4	5	6
1	38.6	39.1	38.1	36.7	36.8	6.8	4.1	3.2	4.5
2	38.6	39.1	38.1	36.9	36.7	6.8	4.3	3.1	4.4
3	34	34.5	33.7	32.6	32.6	5.6	3.6	3.1	3.7
4	34	34.4	33.9	32.4	32.2	5.7	3.8	3.4	3.7
5	39.1	39.5	38.6	37	36.9	7.6	4.1	4.6	4.5
6	38.9	39.4	38.3	36.8	36.8	7.5	4.4	4.3	4.8
7	34.2	34.8	34.2	32.7	32.4	4.8	3.5	3.6	3.6
8	39	39.5	38.8	37.1	37.1	7.5	4.5	4.6	4.5
9	39.2	39.9	38.7	37.4	37.3	7.2	4.5	4.4	4.5
10	42.1	42.5	41.7	40	40	7.4	4.7	5	5.2
11	41.2	41.9	40.7	39.6	39.4	7.6	4.7	4.9	4.7
12	41.9	42.3	41.3	39.5	39.5	7.8	4.9	4.1	5.1
13	41.7	42.3	40.9	39.3	39.3	7.9	4.9	4.1	5.1
14	36.1	36.7	35.5	34.3	34.3	6.7	3.4	3.6	4.5
15	36.3	36.8	35.1	34.1	34	7.4	4.1	4.1	4.9
16	35.2	35.8	34.8	34	34	7.1	4.5	3.8	4.7
17	35.7	36.3	35	33.8	33.7	7.2	4.4	4.1	4.8
18	36.6	37.1	36.2	34.7	34.7	6.7	4.1	3.6	4.6

(1) B.

Number of Bone	Sagittal Diameter of Distal Epiphysis.	Sagittal Diameter at Middle.	Sagittal Diameter at Nutrient Foramen.	Sagittal Diameter at end of Linea Poplitea.	Transverse Diameter at Middle	Transverse Diameter at Nutrient Foramen.	Transverse Diameter at end of Linea Poplitea.	Circumference at Middle.	Circumference at Nutrient Foramen.
	7	8	8a	8b	9	9a	9b	10	10a
1	3.4	2.8	3.5	3	2.2	2.3	2.3	7.9	8.9
2	3.5	2.9	3.5	3.1	2.3	2.4	2.3	7.9	9
3	2.9	2.8	2.9	2.9	1.8	1.9	1.8	7.1	7.6
4	2.8	2.6	2.7	2.7	1.5	1.9	1.6	6.7	7.4
5	3.9	3.6	4	3.8	2.9	3	3	10.6	10.9
6	4	3.9	4.3	4	2.9	3.2	2.9	10.9	11.5
7	2.7	2.3	2.7	2.5	1.9	2.1	2.1	7.1	7.5
8	3.4	2.9	3.3	3.2	2.2	2.4	2.3	8.5	9.2
9	3.6	3	3.3	3.1	1.9	2.3	2.2	8.2	9.2
10	4	3	3.8	3.6	2.4	2.8	2.6	9	10.3
11	4.1	3.2	3.9	3.8	2.4	2.6	2.4	9.3	10.4
12	3.8	3	3.6	3.2	2.2	2.4	2.3	8.8	9.5
13	3.8	3.3	3.7	3.4	2	2.2	2.2	8.7	9.9
14	3.4	2.3	2.5	2.4	1.8	2.1	2.1	6.8	7.4
15	3.6	3.1	3.6	3.1	2	2.5	2.3	8.5	9.4
16	3.8	2.7	3.1	3.1	2	2.2	2.2	7.7	8.7
17	3.7	2.8	3.1	3	2	2.1	2.1	7.6	8.7
18	3.1	2.5	3.2	2.7	1.8	2	1.9	7	8.6

(1) C.

Number of Bone.	Smallest Circumference	Curvature of Tibia.	Retroversion Angle.	Inclination Angle.	Angle of Torsion	Index of Diameters at Middle	Index Cnemicus.	Length Thickness, Index.	Curvature Index.
	10b	11	12	13	14	I	II	III	IV
1	6.8	.2	15.5	13	8	79.29	66.7	17.7	.97
2	6.9	.3	16.5	12	24.5	77.6	66.7	17.6	1.21
3	6.3	.2	15.5	13	26.5	65.5	67.2	18.5	1.02
4	5.8	.3	18.5	14	33	57.7	70.4	17.1	1.53
5	8.6	1	17	13.5	18.5	79.2	75	22	4.11
6	8.7	1	9.5	8	28	73.1	74.4	22.4	3.72
7	6.3	.9	21.5	18	17	82.6	79.2	18.3	3.4
8	7.3	.4	12	9	21.5	74.1	72.7	18.7	1.93
9	7.2	.3	12	9	12	64.4	69.7	18.4	1.31
10	8.9	.4	17	13	22	86.7	72.4	21.1	1.74
11	8.2	.4	17	13	22	75	65.4	19.9	1.63
12	7.6	.7	18.5	15	18	73.3	66.2	18.1	2.98
13	7.3	.5	11	7	26	60.6	59.5	17.5	2.13
14	6	.3	18.5	15	30	78.3	83.7	16.6	1.53
15	7.1	.5	8	5.5	22	64.5	68.1	19.6	2.3
16	7.3	.2	12	10	18.5	74.1	71	10.7	.95
17	7.3	.1	11.5	8	30	72.7	67.7	24.4	.58
18	6.5	.5	14	10.5	3	73.5	63.5	17.9	2.12

(2) A.

	1	1a	1b	2	2a	3	4	5	6
19	36.2	36.9	35.8	34.4	34.4	6.6	4.2	4	4.3
20	37.1	37.7	36.8	35.2	35.2	7.1	5.1	4.1	4.8
21	36.8	37.6	36	35.3	35.1	7.5	5	3.9	4.5
22	38.4	38.9	38.3	36.9	36.8	6.1	3.7	3.7	3.9
23	38.2	38.8	38	36.8	36.8	6.15	3.7	3.7	3.9
24	37.7	38.2	36.7	36.1	35.9	6.2	3.3	2.6	3.8
25	37.6	38.2	37.5	36.2	36.2	6.2	3.4	2.9	3.9
26	41.6	42.2	41.1	40	40	7	5	4	4.6
27	41.7	42.2	41.4	39.9	39.9	7.1	4.9	4	4.4
28	38.3	38.8	38.1	36.8	36.7	6.5	4.6	4.1	4.2
29	38	38.6	37.5	36.4	36.3	6.6	4.8	3.7	4.4
30	34.1	34.5	33.6	36.8	36'8	5.6	4.1	3.8	3.9
31	40.4	40.9	39.9	38.3	38.2	7.8	4.6	3.9	4.9
32	37.5	38.1	37.2	35.7	35.6	7	4.7	4.6	4.6
33	37.3	38	36.8	35.7	35.6	7	4.3	4.1	4.6
34	40.9	41.5	40.3	38.9	38.6	6.2	3.9	3.5	4.4
35	31.6	32.1	31.6	30	30	6.1	3.8	3.6	4
36	36.6	36.9	36.2	35.8	35.7	6.9	4.7	4.5	4.5
37	36.7	37.3	36.2	34.8	34.7	6.6	4.6	4.3	4.4
38	35.7	36.2	35.5	34.4	34.3	5.7	4	3.3	4.3
39	36.7	37.4	36.4	35.3	35.2	6.5	3.7	3.9	4.1
40	33.7	34.1	33.5	32.4	32.4	5.7	3.8	3.4	3.7
41	40.2	40.6	39.6	38.4	38.4	6.5	4.3	3.8	4.4
42	36.7	37.2	35.9	34.6	34.4	7	4.5	3.5	4.2
43	34.5	34.8	34.1	32.9	32.6	5.3	3.9	3.4	3.6
44	34.2	34.9	34.2	32.9	32.7	5.2	3.9	3.1	3.7
45	36.4	36.9	36.2	34.6	34.5	7.1	4.7	4.3	4.5
46	36.8	37.2	36	34.9	34.9	6.8	4.4	4.1	4.4

(2) B.

	7	8	8a	8b	9	9a	9b	10	10a
19	3.1	2.5	3.1	2.7	1.8	2	1.8	6.9	8.4
20	3.2	2.9	3.5	3.3	1.9	2.1	2	7.9	9
21	3.2	3	3.7	3.4	1.8	2.1	2	8	9.3
22	3.3	2.4	3	2.7	1.8	2.2	2.1	7.1	8.1
23	3.1	2.3	2.9	2.7	1.8	2.1	2	6.9	8
24	3.1	2.1	2.5	2.3	1.7	1.8	1.7	6.4	7.1
25	3.1	2.2	2.6	2.5	1.7	1.7	1.8	6.7	7.2
26	3.6	3.1	3.9	3.3	2.4	2.6	2.5	9.6	10.4
27	3.6	3.2	3.7	3.4	2.3	2.6	2.4	8.9	10.3
28	3.4	2.7	3.4	3.1	2	2.3	2.2	7.6	9.3
29	3.4	2.7	3.4	2.9	1.9	2.3	2	7.7	9.1
30	2.7	2.5	2.9	2.7	1.7	1.7	1.6	7.1	7.8
31	3.8	3.2	3.7	3.5	2.2	2.3	2.2	9	9.6
32	3.6	3.2	3.2	3.3	2.3	2.6	2.3	9	10.1
33	3.4	3.2	3.7	3.4	2.1	2.4	2.3	8.8	9.9
34	3.5	2.9	3.3	3.2	1.8	2.1	1.9	8.4	9
35	3.2	2.2	2.6	2.3	1.6	1.8	1.7	6.3	7
36	3.4	3.1	3.8	3.5	2	2.3	2.1	8.7	9.7
37	3.5	3.2	3.8	3.6	2	2.4	2.1	8.7	10
38	3.2	2.8	3.3	3.2	2	2.2	2.1	8.1	8.9
39	3	2.8	3.3	3.1	1.9	2.1	1.8	7.7	8.5
40	3.1	2.1	2.4	2.2	1.6	1.8	1.7	6.2	6.7
41	3.5	3.1	3.7	3.2	2.1	2.2	2.2	8.6	9.4
42	3.4	3.2	3.5	3.3	2.1	2	2.1	7	9.2
43	2.8	2.4	2.7	2.5	1.7	1.8	1.8	6.8	7.5
44	2.7	2.3	2.8	2.5	1.7	1.9	1.8	6.9	7.5
45	3.5	3.2	3.8	3.5	2	2.5	2.2	8.6	10.1
46	3.6	2.9	3.7	3.3	1.9	2.5	2.1	8.7	10.2

(2) C.

	10b	11	12	13	14	I	II	III	IV
19	6.6	.3	10.5	8	0	73.5	64.5	18.2	1.57
20	6.8	.2	23	17.5	9	66.7	59.7	18.3	1.07
21	6.9	.2	17.5	12.5	20	61	57.5	18.6	1.07
22	6.4	.2	15	13.5	26	75	72.9	16.7	.97
23	6.2	.4	21	16	32	78.3	72.4	16.2	1.63
24	5.3	.2	18.5	16	33	82.9	70	14.1	.75
25	5.6	.2	19.5	16.5	36	77.3	65.4	15	.75
26	7.8	.2	19	16	21	77.4	65.4	20.7	.95
27	7.7	0	15.5	11	13	73	70.3	18.5	0
28	7.4	.2	11	8.5	13	74.1	67.6	19.3	.84
29	7.3	.2	10.5	8	25	71.7	66.2	19.2	1.09
30	6.1	.2	10.5	9	4	70	58.6	17.9	1.06
31	7.5	.6	9.5	5.5	5	68.3	62.2	18.6	3.05
32	8.1	.6	19	15	14	70.3	81.3	21.6	2.8
33	8.1	.5	10.5	7	23.5	66.7	63.5	21.7	2.26
34	6.9	.7	14.5	11	12	62.1	63.1	16.7	2.9
35	5.8	0	16.5	13.5	7.5	72.7	69.2	18.2	0
36	7.5	.6	16	11	16	65.6	61.3	24.9	2.98
37	7.7	.6	21	17	22	62.5	63.2	21	2.73
38	7	.4	16	12.5	5	70.9	65.2	19.6	2.38
39	6.6	.3	11	8	20	67.9	64.6	17.9	1.49
40	6.1	0	8	7	23	76.2	72.9	18.3	0
41	7	.8	16	12	12.5	67.7	59.5	17.4	3.6
42	7.6	.5	16	11.5	19	65.6	57.1	20.7	2.51
43	6.1	.3	16	12	15.5	70.8	66.4	17.7	2.03
44	6	.2	18	13	5	73.9	67.3	17.5	1.26
45	7.4	.4	21	16	2	60.9	65.8	20.3	2.04
46	7.6	.3	18	15	9	65.5	68.4	20.7	1.53

(3) A.

	1	1a	1b	2	2a	3	4	5	6
47	38.8	39.2	38.1	36.8	36.8	7.2	4.2	4.2	4.5
48	39	39.4	38.2	36.8	36.7	7.2	4.3	4.2	5.2
49	38.4	38.8	37.6	35.9	35.9	7.9	4.7	4.8	5.1
50	38	38.6	37.4	36	36	7.7	4.4	4.4	5.2
51	36.7	37	36.1	34.8	34.6	6.5	3.8	3.9	4.1
52	36.7	37.3	36.4	35.1	34.8	6.5	3.9	3.6	4.6
53	44.6	45.1	44.1	42.8	42.8	7.4	4.9	4.7	5.2
54	37.4	38	37.1	35.8	35.5	6.3	4.1	3.3	4.1
55	37.8	38.2	36.9	35.7	35.7	6.5	3.9	4	4.4
56	39	39.5	38.2	37.1	36.9	7	4.6	3.9	4.5
57	40.8	41.2	40.1	38.8	38.8	7.4	4.6	4.7	4.8
58	38.1	38.7	37.7	36.6	36.6	6.6	4.5	3.5	4.1
59	38.3	38.9	37.8	36.7	36.7	6.8	4.2	3.9	4.3
60	40.8	41.3	40	38.6	38.5	7	4.9	4.6	4.8
61	40.9	41.3	40	38.7	38.7	7.7	4.9	4	5.4
62	40.7	41.1	40.3	39	38.9	7	4.5	4.5	4.4
63	41.3	41.8	40.8	39.5	39.4	6.9	4.4	4.5	4.6
64	37.3	38	37.2	35.4	35.2	7.3	4.2	4	4.7
65	32.4	32.8	32.5	30	30	5.9	3.3	3.4	2.9
66	38.9	39.3	38.3	37.3	37.3	7	4.3	4	4.6
67	38.9	39.4	38.4	37.1	37	7	4.2	3.8	4.1
68	40	40.6	39.4	38.3	38.2	6.8	4	3.7	4.3
69	40.3	40.9	39.7	38.2	38	6.8	4.2	3.5	4.3
70	36.9	37.2	36.2	35	35	6.6	3.9	4.2	4.1
71	37	37.7	37.2	35.5	35.3	6	4.1	3.5	4.4
72	40.3	40.9	39.7	38.1	37.9	7.3	4.1	3.7	5
73	39.4	40	39	37.7	37.5	7.4	4.5	4	4.4
74	39.5	40.1	39	37.6	37.5	7.2	4.4	3.8	4.6

(3) B.

	7	8	8a	8b	9	9a	9b	10	10a
47	3.6	3.3	3.6	3.5	2.1	2.1	2.1	8.8	9
48	3.7	3.1	3.7	3.6	2.1	2.3	2.2	8.6	9.5
49	3.3	3.2	3.9	3.6	2.2	2.5	2.4	8.8	10.3
50	3.6	3.2	3.9	3.5	2.4	2.5	2.4	8.7	10.3
51	3.4	2.7	3.3	2.8	1.9	2.2	2	7.8	8.5
52	3.3	2.7	3.1	2.8	2	2.1	2	7.7	8.6
53	3.6	3.5	3.8	3.6	2.4	2.8	2.5	9.5	10.5
54	3.2	3.4	4	3.5	2	2	2	8.9	9.7
55	3.3	3.2	3.6	3.3	2	2.1	2.1	8.6	9.4
56	3.1	3.4	3.8	3.7	2.2	2.4	2.3	9.1	9.8
57	3.7	3.4	3.6	3.6	2.2	2.5	2.3	8.9	9.8
58	3.2	2.9	3.3	2.9	2	2.2	2.1	8	8.6
59	3	3	3.3	3.1	2.2	2.4	2.2	8.6	9.3
60	3.8	3.3	4.1	4	2.1	2.5	2.4	9.6	10.4
61	4	3.4	4.1	3.9	2.3	2.6	2.5	9.6	10.9
62	3.5	3.1	3.7	3.5	2.4	2.5	2.6	9	9.9
63	3.7	3	3.6	3.4	2.3	2.5	2.4	9	9.6
64	3.7	2.9	3.5	3.1	1.9	2.1	1.9	7.9	9
65	2.4	2.6	2.6	2.6	1.8	1.9	1.8	7	7.4
66	3.6	3.2	3.8	3.4	2.2	2.5	2.3	9.3	10
67	3.5	3.1	3.7	3.4	2.3	2.5	2.4	9.1	9.9
68	3.1	3.1	3.6	3.5	2.1	2.1	2.1	8.8	9.3
69	3.1	3.3	3.7	3.5	2	2.1	2.1	8.7	9.4
70	3.1	3.2	3.5	3.3	2.4	2.5	2.5	9.4	9.8
71	3.2	3.1	3.6	3.3	2.3	2.4	2.3	9	9.6
72	3.5	3.4	3.8	3.6	2.2	2.4	2.2	9	10.1
73	3.3	3.1	3.6	3.2	2.2	2.2	2.2	9	9.4
74	3.5	3.1	3.6	3.2	3.1	2.2	2.1	8.8	9.4

(3) C.

	10b	11	12	13	14	I	II	III	IV
47	7	.5	17.5	13	7	64.6	60.9	18	2.55
48	7.2	.5	13	10	25	66.1	63	18.5	2.38
49	7.2	.5	19	14.5	25	68.8	64.1	18.8	2.27
50	7.5	.5	14.5	12.5	19	75	64.1	19.7	2.17
51	6.8	.5	18	16.5	3.5	69.8	65.2	18.5	2.2
52	6.6	.6	16	13	10	72.2	67.7	18	2.51
53	8.2	.5	17	13	10	69.6	72.4	18.4	1.9
54	7.2	.7	19.5	15	10	58.8	50	19.3	3.07
55	7.1	.8	17.5	11.5	3	62.5	58.3	18.8	3.5
56	7.3	.6	18	13	19	63.2	64	18.7	2.72
57	7.6	.5	15	12	7.5	63.2	68.1	18.6	2.38
58	6.8	.4	15	12.5	39	70.2	67.7	17.7	2.02
59	7	.5	14	10	17	72.9	72.7	18.3	2.33
60	8	4	10	8	19	63.6	60.5	19.6	1.77
61	8.1	.4	15	10.5	16	68.7	62.2	19.8	1.77
62	7.8	.4	14	11	12	78.7	68.5	19.1	1.8
63	7.7	.5	18	13	22	76.7	68.1	18.6	2.13
64	6.7	.5	9.5	5.5	20	63.8	60	18	2.56
65	6.1	.5	19	17	14.5	76.6	73.1	18.8	2.68
66	8	.8	25	20.5	15	68.7	65.3	20.6	3.43
67	8	.9	22	18	25	72.6	68.5	20.6	3.86
68	7.4	.9	22	17	12	66.1	58	18.5	3.6
69	7.3	.9	23	18	6	61.5	56.8	18.1	3.6
70	7.6	.4	12	9	21	75	72.5	20.6	1.96
71	7.6	.4	21.5	17	14.5	74.2	65.3	20.5	1.87
72	8	.4	18	14	21	64.2	62.7	19.9	1.76
73	7.6	.6	14.5	11	6	70.5	61.1	19.3	2.83
74	7.9	.6	12	7.5	9	101.6	61.1	20	2.83

(4) A.

	1	1a	1b	2	2a	3	4	5	6
75	37.7	38.1	37.2	35.8	35.7	6.9	4.2	3.3	4.6
76	37.8	38.6	37.4	36.1	35.9	6.9	4.3	4.1	4.6
77	35.2	35.6	34.7	33.5	33.5	6	3.6	3.3	4.3
78	34.8	35.4	34.6	33.4	33.4	6.2	3.7	3.6	4.1
79	41.9	42.4	41.3	39.9	39.8	7.4	4.6	4.1	4.6
80	41.7	42.4	41.1	39.6	39.6	7.4	4.7	4.1	5
81	34.9	35.4	34.6	33.3	33.3	6.1	3.9	3.5	3.9
82	35.3	35.8	35.1	33.6	33.6	6.3	3.8	3.5	3.9
83	39.9	40.5	39.4	37.6	37.4	7.6	4.6	4	4.7
84	36.1	36.6	35.7	34.2	34	6.9	4.1	4.2	4.7
85	41.3	41.8	40.5	39.2	39	7	4.4	4	4.5
86	39.1	39.7	38.8	37.6	37.4	6.7	3.9	4.2	4.4
87	38.8	39.7	39.4	39.5	39.6	6.8	3.6	3.6	4.1
88	37.8	38.1	37.3	35.9	35.9	6.9	4	4.5	4.9
89	37.6	38.1	36.9	35.8	35.8	7.1	4.2	3.5	4.4
90	37.4	37.8	37.1	35.9	35.9	7	4.3	3.7	4.3
91	35.5	36.1	35.5	34.4	35.2	6.2	3.7	3.7	4
92	35.7	36.4	35.6	34.4	34.4	6.2	3.7	3.7	4
93	33.5	34	33.3	31.8	31.8	6.1	3.8	3.4	4
94	33.5	34.1	33.4	31.9	31.9	6.1	3.8	3.1	3.7
95	34.7	35.2	34.4	32.1	31.5	5.9	3.7	3.7	4.1
96	39.3	40.2	38.5	37.1	36.9	7.5	4.4	4	5
97	37.9	38.3	37.2	35.9	35.9	7.3	4.6	3.7	4.9
98	38.7	39	38	36.6	36.6	7.3	4.7	4	4.8
99	39.1	39.7	38.4	36.9	36.7	7.4	4.5	4.2	4.9
100	36.8	37.2	36.3	35	34.9	6.7	4	3.8	4.6
101	36.6	37.2	36.2	34.8	34.8	6.6	3.7	3.7	4.5
102	37.2	38.2	36.9	35.2	35.2	7.3	4.5	4	4.9

(4) B.

	7	8	8a	8b	9	9a	9b	10	10a
75	3.4	3.2	3.7	3.4	1.9	2.2	2.1	8.5	9.5
76	3.4	3.2	3.7	3.5	1.9	2.1	2	8.4	9.2
77	2.9	2.4	2.9	2.7	1.7	2	1.9	7	8
78	2.9	2.4	2.7	2.6	1.8	1.9	1.9	7.1	7.7
79	3.6	3.2	3.4	3.2	2.2	2.5	2.3	8.9	9.8
80	3.6	3.1	3.7	3.3	2.1	2.4	2.2	9.1	9.8
81	2.8	2.3	2.9	2.8	1.8	1.9	1.9	6.9	7.6
82	2.7	2.6	2.9	2.9	1.9	2	2	7.1	7.6
83	3.6	3.2	3.9	3.3	2.1	2.2	2.2	9.3	10.3
84	3.3	3.1	3.7	3.3	1.2	2.3	2.2	8.6	9.5
85	3.6	3.2	3.7	3.3	1.9	2.2	2.2	8.6	9.5
86	3.3	2.7	3.3	2.9	1.8	2.1	1.9	7.8	9.1
87	3.2	2.6	2.8	2.8	1.7	2.2	2	7.3	8.3
88	3.2	3	3.4	3.4	1.9	2	2	8.2	9.3
89	3.2	3.1	3.6	3.2	2	2.2	2.1	8.4	9.5
90	3.1	3.1	3.6	3.3	2	2.2	2	8.5	9.4
91	3.3	2.3	2.8	2.4	1.75	1.9	1.7	6.6	7.5
92	3.2	2.4	2.9	2.5	1.7	1.9	1.8	6.6	7.7
93	2.9	2.3	2.7	2.4	1.7	1.7	1.7	6.5	7.3
94	3	2.3	2.9	2.5	1.7	1.8	1.7	6.5	7.7
95	3	2.4	2.9	2.6	1.8	1.9	1.8	7	7.8
96	3.4	2.9	3.6	3.1	2	2.2	2.1	8	9.1
97	3.4	2.8	3.7	2.9	2.1	2.2	2.1	8	9.3
98	3.2	2.8	3.6	2.9	2.1	2.3	2.1	8.1	9.2
99	3.4	2.9	3.7	3.1	2.1	2.3	2.2	8.2	9.5
100	3.2	4	3.6	4.1	2.8	2.4	2.6	11.1	9.8
101	3	3	3.3	3.2	2	2.4	2.2	8.5	9.2
102	3.5	3	3.4	3.2	2.2	2.2	2.2	8.2	8.9

(4) C.

	10b	11	12	13	14	I	II	III	IV
75	7.4	.8	13	10	7.5	59.4	58.9	7.5	3.6
76	7.4	.5	14	11.5	12.5	60.3	57.5	19.3	2.25
77	6.3	.3	21.5	17	8.5	72.3	68.8	17.9	1.5
78	6.2	.2	12	10	30	75	70.4	17.8	1.12
79	7.5	.5	15	11	17.5	69.8	72.1	17.9	2.48
80	7.6	.4	15.5	10	16	67.7	64.9	18.2	1.78
81	6.1	.3	17.5	13	13.5	78.3	65.5	17.5	1.64
82	6.1	.3	20.5	16	19	71.2	68.4	17.3	1.64
83	7.8	1	23	18	20	65.6	56.4	19.5	4.11
84	7.7	.6	16	12	25	37.7	63	21.2	2.94
85	7.4	.5	17	12	21.5	60.3	59.5	17.8	2.3
86	7	.5	11.5	8.5	20.5	64.8	63.6	17.8	2.55
87	6.9	.5	15.5	12	20	65.4	78.6	17.8	2.7
88	7.3	.6	12	8.5	26	63.3	58.8	19.3	2.92
89	7.5	.5	16	11	29	65.6	62	19.9	2.42
90	7.3	.8	21	17	2	65.5	59.7	19.5	4.12
91	6.1	.3	13.5	11.5	32	76.1	69.1	17.2	1.72
92	6.2	.3	11	8	41	70.2	63.8	17.5	1.8
93	6.1	.3	9	5.5	10.5	73.3	63	18.2	1.64
94	5.9	.3	6	3.5	15	71.7	62.1	17.6	2.04
95	6.3	.3	11	8.5	23.5	72.9	66.7	18.2	1.67
96	7	.3	18	15	26	69	59.7	17.8	1.5
97	7.2	.4	22.5	16	30	73.2	60.3	19	2.14
98	7.2	.5	20	17	17	73.2	62.5	18.6	2.46
99	7.2	.3	18	12.5	29	72.4	63	18.4	1.67
100	8.8	.9	21.5	16.5	7	70	66.2	23.9	4.18
101	7.2	.7	15	12	31.5	66.1	72.7	19.5	3.43
102	7.4	.5	12.5	9	6	71.7	63.2	19.9	2.59

(5) A.

	1	1a	1b	2	2a	3	4	5	6
103	36.9	37.6	36.8	35.1	35.1	7.4	4.5	3.8	4.8
104	34.7	35.3	34.3	33.2	33	6.2	4	4	4
105	37.8	42.2	41.2	39.9	39.2	6.8	4.6	4.6	4.6
106	42.2	42.7	41.6	40	39	7	4.7	4.4	4.6
107	39.3	39.9	39.1	37.5	37.5	7	4.2	4.3	4.9
108	39.8	40.4	39.7	38	38	7.1	4.3	4.1	4.9
109	34.6	35	34.4	33.1	33.1	6.3	4	3.7	4.1
110	34.5	35.1	34.3	32.9	32.8	6.4	4	3.6	4
111	41.4	41.7	41.1	39.5	39.2	7.4	4.7	4.1	4.7
112	41.3	41.9	40.8	39.4	39.2	7.5	4.7	3.6	4.7
113	34.7	35	34.2	32.9	32.8	6.4	4	3.6	4.3
114	34.8	35.3	34.2	32.9	32.9	6.5	4	3.8	4
115	36.7	37.4	36.7	35.1	34.8	6.6	3.9	3.7	4.2
116	36.1	36.6	36	34.3	34.2	6.5	4.1	3.1	4.1
117	36.4	37	36.7	34.7	34.5	7	4.2	3.6	4.3
118	37.1	37.7	36.7	35.1	35.1	6.6	4.1	4	4.5
119	39.3	39.4	39	37.1	37	7.4	4.8	4.2	4.7
120	37.7	38.3	37.3	35.7	35.7	7.7	4.1	4.1	5.2
121	39.2	39.8	38.5	37.1	37	8.4	4.8	4.1	5
122	37.2	38.4	37	35.7	35.7	6.5	3.5	3.5	4.1
123	33.5	34	33.2	31.9	31.8	6.2	3.6	3.7	4
124	34	34.5	33.7	32.3	32.2	6.1	3.9	3.5	4.1
125	41.7	42.2	41.3	39.5	39.3	7.4	4.7	4.6	5
126	41.2	42.1	40.8	39.2	39.2	7.6	4.9	4.2	4.7
127	39.2	39.7	38.7	37	37	7.8	4.6	4.3	4.9
128	39.1	39.4	38.6	36.8	36.8	7.7	4.5	4.2	5
129	33.9	34.3	33.9	33	32.5	6.2	3.8	3.2	4.2
130	33.7	34.2	33.7	32.2	32.2	6.3	3.7	3.7	4.3

(5) B.

	7	8	8a	8b	9	9a	9b	10	10a
103	3.5	3	3.3	3.1	2.1	2.2	2.2	8	8.6
104	3.1	2.4	2.8	2.6	1.7	1.9	1.8	6.8	7.6
105	3.3	3.6	3.8	3.6	2	2.6	2.1	9.9	10.6
106	3.7	3.6	3.9	3.9	2.4	3	2.2	10.1	11.1
107	3.5	3	3.6	3.2	1.9	2.1	2	8.3	9
108	3.5	2.9	3.6	3.3	1.8	2.1	1.8	8.4	9.1
109	3.2	2.3	2.7	2.3	1.6	1.8	1.6	6.5	7.6
110	3.1	2.4	2.8	2.6	1.5	1.8	1.6	6.6	7.6
111	3.7	3.3	4	3.5	2.2	2.2	2.3	9	10.2
112	3.7	3.4	4	3.6	2.2	2.4	2.3	9.3	10.2
113	3	2.4	2.8	2.6	1.7	1.9	1.7	7.1	7.6
114	3	2.5	2.9	2.6	1.6	1.9	1.7	7.4	7.9
115	2.9	2.7	3	2.9	1.8	1.8	1.8	7.6	8.3
116	2.8	2.8	3.2	3	1.8	1.8	1.8	7 7	8.1
117	3.3	2.7	3.4	2.9	1.9	2.1	2	7.8	8.8
118	3.4	2.7	3	2.8	1.9	2	1.9	7.6	8.2
119	3.6	3.4	4	3.4	2.2	2.4	2.3	9.1	10
120	3.4	3.2	3.7	3.3	2.2	2.5	2.3	8.9	9.7
121	3.7	3	3.8	3.3	2.3	2.5	2.1	8.6	9.8
122	3.1	2.6	3.3	2.7	1.8	2	1.7	7.3	8.4
123	3.1	2.2	2.7	2.3	1.5	1.8	1.7	6.1	7.1
124	3	2.1	2.5	2.3	1.6	1.7	1.6	6.1	7.1
125	3.8	3.3	3.9	3.5	2.1	2.5	2.3	9.1	10
126	3.8	3.3	4	3.8	2.3	2.6	2.5	9.2	10.3
127	3.5	3.2	3.9	3.3	2	2.6	2	8.7	10.2
128	3.5	3.2	3.9	3.4	2.2	2.5	2.2	8.8	9.8
129	2.9	2.6	3.1	2.7	1.7	1.9	1.7	7.1	8.3
130	3	2.5	3.1	2.8	1.6	2.1	1.7	7.1	8.4

(5) C.

	10b	11	12	13	14	I	II	III	IV
103	7.3	.5	11.5	6.5	24	71.2	67.7	19.8	2.92
104	6.3	.3	10	6.5	34	70.8	67.3	18.2	1.8
105	7.7	1	25	20	21.5	54.2	68.4	20.1	4.08
106	8	1.1	26.5	20	55.5	65.3	76.6	19	4.31
107	7.4	1	20.5	15	6.5	62.7	59.2	18.7	4.5
108	7	1	20.5	15.5	23.5	62.1	59.2	17.5	4
109	6.1	.4	20	16	2.5	71.1	66.7	17.6	2.14
110	6.1	.4	18.5	13	24	63.8	63.6	17.7	2.38
111	7.8	.5	19	15	15.5	66.7	54.4	18.8	2.24
112	7.9	.5	17	12.5	31	63.2	58.8	19.1	2.36
113	6.1	.4	15.5	12	1.5	70.2	68	17.6	2.07
114	6.3	.5	21.5	16	12	64	65.5	17.4	2.37
115	7	.3	26	21.5	7.5	64.8	60	19.1	1.62
116	6.6	.7	29	23	16.5	62.5	56.3	18.3	3.13
117	7	.4	21	15	20	68.5	61.8	19.2	1.81
118	6.8	.4	24	18.5	28	69.8	66.7	18.3	2.22
119	8	.5	24	18.5	9.5	64.7	58.8	20.4	2.17
120	7.6	.4	14	9	10	69.8	67.6	20.2	1.8
121	7.9	.5	15	11	17	78	65.3	20.2	2.36
122	6.4	.3	8.5	5	25	69.2	61.5	17.2	1.46
123	5.5	.2	18.5	15	8.5	69.8	67.9	16.3	1.3
124	5.9	.1	17.5	12.5	30	73.8	68	17.4	.72
125	7.8	.3	19	16	6	63.6	62.8	18.7	1.44
126	7.7	.3	14.5	10	19.5	69.7	64.6	18.7	1.44
127	8	.3	16.5	11	27.5	62.5	67.5	20.4	1.35
128	7.9	.3	16.5	11.5	19	67.2	62.8	20.2	1.35
129	6.5	.4	23.5	19.5	.5	66.7	61.3	19	2.09
130	6.5	.3	17	11.5	11.5	64	66.1	19.3	1.5

(6) A

	1	1a	1b	2	2a	3	4	5	6
131	38.5	38.7	38	37.8	37.7	6.5	4	3.6	4.1
132	38.2	38.9	37.9	36.5	36.5	6.5	4.2	3.6	4.5
133	39.2	39.6	38.9	37.4	37.1	7.1	4.1	3.7	4.8
134	38.9	39.6	38.8	37.1	37	7	4.1	3.4	4.5
135	40.3	40.7	40.1	38.5	38.5	7	4.7	3.6	4.7
136	40.5	41.2	40.1	38.9	38.9	7.1	4.7	3.9	4.8
137	42.2	42.7	41.8	40.3	40.2	6.5	4.5	4.6	4.6
138	42.8	43.2	42	41	41	7.2	4.4	3.9	4.5
139	38	38.5	37.8	36.4	36.4	6.8	4.1	3.7	4.5
140	38.1	38.6	37.3	36	36	7.4	4.1	4	4.5
141	43.1	43.5	42.7	41.3	41.3	7.7	4.5	4.4	5
142	43.4	43.7	42.5	41.2	41.2	7.9	4.8	4.3	4.9
143	39	39.5	38.8	37.5	37.5	6.1	3.6	3.9	4
144	39.2	40	39	37.9	37.8	6.2	3.6	3.5	3.9
145	40.9	41.4	40.7	39.2	39.2	7.2	4.6	4.4	4.6
146	40.6	41.3	40.5	38.9	38.9	7.2	4.5	4.3	4.5
147	38.7	39.1	38.2	36.8	36.8	7.2	4	3.8	4.7
148	39.5	39.9	39.1	37.5	37.4	7	4.2	4.1	4.3
149	36.6	36.8	36.3	34.8	34.8	6.6	3.9	3.3	4.2
150	39.1	39.4	38.9	37.3	37.1	6.9	4.2	4.1	4.4
151	38.2	38.6	37.6	36.4	36.3	7	4.3	4.2	4.6
152	40.7	41.1	40.2	38.8	38.7	6.8	4.2	3.7	4.5
153	40.6	41.1	40.4	38.8	38.5	6.8	3.9	3.9	4.4
154	39.3	39.6	38.8	37.1	37.1	6.9	4.5	4	4.8
155	40	40.3	39.6	38.1	38	6.8	4.4	3.8	4.2
156	39.1	39.5	38.8	37.3	37.3	6.9	4.1	3.8	4.6
157	37.5	37.9	37.3	35.6	35.6	6.5	4	3.5	4.2
158	34.9	35.4	34.6	33.6	33.6	6.3	3.6	3.6	3.8

(6) B.

	7	8	8a	8b	9	9a	9b	10	10a
131	3	2.5	2.9	2.6	1.7	1.9	1.7	7	7.6
132	3.1	2.7	3	2.8	1.7	1.9	1.7	7.3	7.9
133	3.1	2.8	3.2	3	1.9	2.2	2	8.2	8.7
134	3.1	2.7	3.3	3	1.8	2.2	2.1	7.9	8.9
135	3.3	3.3	3.8	3.6	1.9	2.1	2.1	9	9.6
136	3.4	3.2	3.8	3.5	2.2	2.3	2.2	8.7	9.8
137	3.8	2.9	3.4	3	2.1	2.5	2.1	8.1	9.5
138	3.6	2.7	3.3	2.8	1.9	2.1	2	7.6	8.9
139	3.5	2.9	3.4	2.9	1.9	2.3	1.9	7.9	9
140	3.5	2.9	3.4	3	2.3	2.5	2.4	8.5	9.4
141	3.8	3.4	3.7	3.4	2.4	2.6	2.4	9.6	10
142	3.8	3.2	3.8	3.4	2.4	2.5	2.4	9.3	9.9
143	2.9	2.3	2.6	2.4	1.5	1.7	1.7	6.3	6.9
144	3	2.6	2.6	2.4	2	1.7	1.8	7.7	6.9
145	3.4	3	3.4	3.1	2.2	2.2	2.1	8.5	9.1
146	3.5	2.8	3.4	3.1	2.2	2.2	2.2	8.5	9.2
147	3.3	2.9	3.2	3.1	2.1	2	2.4	8.4	9.3
148	3.3	2.8	3	2.9	2	2.3	2	7.8	8.6
149	3.2	2.5	3	2.7	1.8	1.8	1.8	6.9	7.8
150	3.2	2.6	3	2.9	2	2.2	2.1	7.7	8.4
151	3.4	2.8	3.3	2.9	1.8	2.2	1.8	7.5	8.9
152	3.1	3.9	3.3	3.2	1.7	1.8	1.7	8.2	8.5
153	3.2	2.9	3.2	3.1	1.7	1.8	1.8	8.3	8.6
154	3.3	2.9	3.5	3.1	1.9	2.4	2.1	8.6	9.3
155	3.4	2.8	3.3	3	1.8	2.3	1.9	8.3	9.1
156	3.4	2.9	3.3	3.1	2.1	2.4	2.3	8	8.9
157	3.1	2.5	3	2.6	1.5	1.8	1.6	6.7	7.6
158	2.9	2.4	2.8	2.5	1.4	1.7	1.5	6.4	7.3

(6) C.

	10b	11	12	13	14	I	II	III	IV
131	6.1	.4	20	15.5	0	68	66.7	15.8	1.8
132	6.2	.5	22.5	17	5.5	64.2	63.3	16.2	2.12
133	6.8	.7	20	16	12.5	66.1	68.8	17.4	2.74
134	6.7	.5	15.5	21	15.5	66.7	67.7	17.2	1.88
135	7.8	.5	18	15	4.5	57.6	56	19.2	2.4
136	7.6	.4	9	5.5	21.5	67.2	59.2	18.8	1.63
137	7.1	.4	16.5	12	15.5	72.4	73.5	16.8	1.78
138	6.8	.4	12.5	8.5	24	68.5	63.6	15.9	1.92
139	6.6	.5	12	9	16	65.5	67.6	17.4	2.46
140	7.3	.3	13.5	9.5	22	77.6	86.2	19.2	1.47
141	8.2	.6	20	16	6.5	71.6	68.9	19	2.45
142	8.4	.4	16.5	13	21.5	75	66.7	19.4	1.63
143	5.5	.3	11.5	9.5	26	66.7	63.5	14.1	1.6
144	5.5	.2	7	4.5	39.5	76.9	65.4	14	1.06
145	7.3	.6	22	17.5	14	74.6	63.2	17.8	2.35
146	7.3	.6	18	13.5	30.5	64.2	65.7	17.9	2.92
147	7.2	.4	16.5	12.5	5	73.7	75	18.6	2.02
148	7	.8	20	15	15.5	70.9	75	17.7	3.48
149	6.6	.1	18.5	15	2	73.5	61.7	17.9	.62
150	6.8	.6	18	15	7	76.9	74.6	17.3	3.06
151	6.4	.3	10	8	33	62.5	66.7	16.8	1.43
152	6.6	1.2	25	18.5	3	44.2	54.5	16.2	4.7
153	6.6	1.2	20.5	16	28	57.9	54.7	16.3	5.06
154	7.3	.8	25	20	13.5	65.5	67.1	18.6	3.62
155	7.3	.5	21.5	17	30.5	65.5	70.8	18.3	2.26
156	7	.3	16.5	13	12.5	71.9	72.7	17.9	1.42
157	6.1	.5	18	13	33	61.2	60	16.3	2.18
158	5.6	.3	15	10.5	16	58.3	61.8	16	1.57

(7) A.

	1	1a	1b	2	2a	3	4	5	6
159	36.8	37.2	36.4	34.9	34.9	6.7	4.3	3.6	3.8
160	37.8	38.5	37.8	36.6	36.6	6.3	3.6	4.1	3.2
161	42.3	42.7	41.9	40.8	40.8	7.2	4.4	4.2	4.7
162	40.1	42.5	41.7	40.2	40.2	7.5	4.5	4.9	4.7
163	37.2	37.8	37.2	35.6	35.6	6.6	4.1	3.6	4
164	37.3	37.9	37.3	35.5	35.5	6.6	4	3.4	4.2
165	36.4	36.6	36	34.6	34.6	5.7	3.9	3.6	3.7
166	39.5	39.9	39.5	38.1	38.1	6.5	4.2	3.8	4.5
167	39.3	40	39.3	37.9	37.9	6.6	4.3	3.5	4.3
168	38.8	39.3	38.6	37.1	37.1	6.4	4.1	4.1	4
169	39.7	40.1	39.5	38	37.7	6.6	4.2	4.2	4.4
170	41.1	41.3	40.6	39.3	39.3	7.5	4.3	3.9	4.9
171	41.1	41.6	40.8	39.5	39.5	7.7	4.5	4.3	4.9
172	41.1	41.3	40.2	39.2	39.2	7.1	5.2	4.4	5
173	36.6	37.1	36.1	34.9	34.9	6.4	4	3.6	3.8
174	39.6	39.9	39.1	38	38	7	4.4	3.8	4.4
175	38	38.5	37.4	36.2	36.2	6.9	4.5	3.9	4.3
176	37.6	38.2	37.4	36.3	36.2	6.8	4.4	3.5	4
177	37.2	37.5	36.8	35.2	35	7.1	4.6	3.6	4.6
178	37.3	37.8	37	35.4	35.1	7.3	4.7	3.8	4.5
179	37.9	38.4	37.4	35.9	35.9	7.3	4.4	3.8	4.8
180	38.4	38.7	37.8	36.5	36.5	7.1	4.3	3.9	4.6
181	38.3	38.7	37.7	36.4	36.4	7.1	4.3	3.9	4.5
182	36.8	37.5	36.5	35.2	35.2	6.5	4.1	3.6	4.6
183	36.9	37.2	36.6	35.1	35.1	6.9	4.1	4.2	4.5
184	36.9	37.4	36.6	35.2	35.2	6.4	3.9	3.6	4.3
185	36.5	37.1	36	34.8	34.8	6.8	3.9	3.4	4.3
186	37.9	38.4	37.5	36.6	36.6	7.4	4.2	4	4.9

(7) B.

	7	8	8a	8b	9	9a	9b	10	10a
159	3.1	2.5	3	2.8	1.9	1.9	2	7	7.8
160	2.4	2.9	2.6	1.7	1.9	1.7	1.7	6.6	7.6
161	3.5	2.7	3.2	2.9	1.9	2.1	2	7.6	8.6
162	3.8	2.8	3.3	2.9	1.9	2.3	1.9	7.9	8.8
163	3	2.6	2.9	2.7	1.7	1.9	1.8	7	7.8
164	3.1	2.8	3.3	3	1.7	2.2	1.8	7.6	9.1
165	3	2.3	2.6	2.5	1.8	2	1.9	6.7	7.3
166	3.2	2.8	3	3	1.8	1.8	1.7	7.7	8.3
167	3.3	2.8	3	2.9	1.7	1.8	1.6	7.3	8.1
168	3.4	2.5	2.8	2.5	1.9	2	1.9	7.3	7.9
169	3.4	2.5	2.9	2.5	1.7	2	1.7	7	7.9
170	3.6	3.1	3.5	3.3	1.9	2.1	2.1	8.3	9
171	3.7	3	3.6	3.3	2	2.1	2.1	8.2	9.2
172	3.5	3.3	3.8	3.4	2.4	2.6	2.5	9.6	10.5
173	3.1	2.3	2.6	2.4	1.8	2	1.8	6.7	7.4
174	3.4	2.9	3.3	3.3	2.1	2.2	2.3	8.4	9.3
175	3.5	2.9	3.2	3	1.8	2	1.8	7.7	8.6
176	3.3	2.6	2.9	2.8	1.7	1.8	1.7	6.9	7.7
177	3.6	3	3.7	3.2	1.9	2.2	2.1	8.3	9.3
178	3.5	3	3.6	3.2	1.9	2.1	2	8.3	9.2
179	3.8	3.3	3.8	3.5	2.1	2.3	2.2	8.7	9.7
180	3.4	3.1	3.5	3.5	2	2.3	2.1	8.6	9.4
181	3.4	3	3.4	3.2	2	2.3	2.1	8.2	9.1
182	3.2	2.6	3.3	2.7	2	2.3	2	7.6	8.8
183	3.4	2.7	3.3	2.9	2	2.3	2	7.7	9
184	3.3	2.4	2.8	2.7	1.9	2	2	7.8	7.7
185	3.3	2.3	2.7	2.5	1.9	1.9	1.9	7.5	7.4
186	3.7	3.4	3.7	3.6	1.9	2.2	2.1	8.8	9.5

(7) C.

	10b	11	12	13	14	I	II	III	IV
159	6.2	0	18.5	15	23	74	64.4	16.7	0
160	6.1	.2	10	5.5	39	68.8	63.8	16.1	1.06
161	6.6	.2	19	14.5	9	69.8	64.1	15.6	.93
162	6.9	.5	13	8	35	67.9	68.2	17.2	2.23
163	6.1	.4	18.5	15	2	65.4	63.8	16.4	1.96
164	6.4	.6	22.5	16.5	27	60.7	66.7	17	2.94
165	6	.1	17	14.5	3.5	80	78.4	16.5	.56
166	6.9	.4	15	11.5	18	65.5	60	17.3	1.78
167	6.5	.1	14	10	29	60	60	16.5	.44
168	6.4	.1	15	12	16	77.6	71.4	16.5	.52
169	6.4	.1	16	13	34	68	67.2	16.1	.52
170	7.3	.4	10	7	26.5	59.6	60	17.8	1.79
171	7.3	.4	15	10.5	29	66.7	58.3	17.9	1.79
172	8.4	.6	22	19	21	73.8	69.3	20.3	3.4
173	6.2	.1	19	15	26.5	78.3	75	16.9	.56
174	6.8	.5	23	18	17	72.4	66.7	17.2	2.72
175	6.8	.4	18	13.5	12	62.1	55.6	17.9	2.11
176	6.3	.1	12	7.5	24	65.4	62.1	16.8	.56
177	7.2	.3	22	16	15	63.3	60.3	19.4	1.6
178	7.2	.4	19	14	30	63.3	58.3	19.3	1.82
179	7.7	.6	17.5	13	6.5	63.6	60.5	20.2	2.64
180	7.3	.8	22	17.5	8	64.5	65.7	19	3.26
181	7.4	.5	14.5	10	21	67.8	68.7	19.3	2.04
182	6.5	.3	16	12	11	76.9	70.8	17.7	1.6
183	6.7	.2	12	9.5	28	74.1	69.7	18.2	1.02
184	6.3	0	13	9.5	5	80.9	69.6	17.1	0
185	6.2	0	10	7	10	80.4	70.4	17	0
186	7.7	.8	19	15	7	55.9	59.5	20.2	3.64

(8) A.

	1	1a	1b	2	2a	3	4	5	6
187	39.8	40	39.2	37.4	37.4	7.6	5.3	3.7	5.1
188	40.7	41.4	40.3	38.8	38.8	7.9	4.6	4.4	5.1
189	40.7	41	40.1	38.4	38.4	7.6	4.7	4.6	4.9
190	40.1	40.7	39.6	37.7	37.7	7.8	4.7	3.7	4.9
191	40.8	41.1	40.5	38.8	38.7	7.2	4.6	3.4	4.8
192	41	41.7	40.9	39.2	39.2	7.3	4.6	3.6	4.8
193	35.7	36.3	35.5	34.2	34.2	6	3.7	3.1	4.3
194	42.1	42.3	41.2	39.6	39.6	7.5	5	3.6	4.9
195	41.8	42.3	41.3	39.6	39.6	7.5	4.8	3.7	4.9
196	37.3	38	37.2	35.5	35.5	7	4	3.9	4.7
197	39.6	40	39	37.4	37.4	7.7	4.5	3.9	4.6
198	39.4	39.9	38.9	37.4	37.4	7.6	4.4	4	4.6
199	34.4	34.6	33.7	32.3	32.1	6.9	4.7	3.9	4.3
200	34	34.5	33.6	32	31.8	7.1	4.4	4.3	4.4
201	37.1	37.3	36.4	34.5	34.5	7.9	5.4	4.6	5
202	37.2	37.6	36.9	34.6	35.6	7.8	5.3	4.7	4.9
203	40.2	40.8	39.8	38.8	38.8	7.2	4.3	3.7	4.5
204	40.3	40.9	40.1	38.7	38.5	7.2	4.4	3.8	4.5
205	44.6	45.1	44.3	42.2	42.2	7.8	5.1	4.7	5
206	43.9	44.5	43.6	42	42	7.9	4.9	4.8	4.9
207	36.1	36.7	36.1	34.5	34.5	6.7	4.9	3.3	4.2
208	36.8	37.5	36.6	35.3	35.3	6.8	4.3	3.3	4.2
209	36.4	36.5	35.8	34.1	34	7.2	4.4	4	4.6
210	33.5	33.8	33.2	31.5	31.5	7.8	4.1	3.4	4.4
211	33	33.6	33	31.1	31.1	6.4	4.2	3.8	4.2
212	40.9	41.2	40.2	38.9	38.9	7.3	5.4	4.2	4.7
213	37.7	38	36.7	35.8	35.8	6.7	4.3	3.7	4.5
214	37.7	38	37.3	36.1	36	6.6	4.2	3.4	4

(8) B.

	7	8	8a	8b	9	9a	9b	10	10a
187	3.6	3.2	3.6	3.4	2	2.1	2.1	8.7	9.3
188	3.5	3	3.5	3.2	2.3	2.5	2.3	8.6	9.6
189	3.6	3.1	3.6	3.3	2.3	2.6	2.3	8.7	9.8
190	3.7	3.2	3.8	3.4	2	2.3	2.1	8.6	9.9
191	3.5	3.1	3.7	3.2	2	2.2	2.1	8.5	9.5
192	3.7	3.1	3.7	3.2	2	2.2	2	8.4	9.5
193	3	2.6	3	2.9	1.8	1.9	1.8	7.2	7.7
194	3.7	3.2	4.1	3.5	2.2	2.5	2.2	9.2	10.5
195	3.7	3.2	3.9	3.5	2.1	2.4	2.1	9	10.3
196	3.5	3	3.2	3.3	2	2	2	8.4	8.7
197	3.7	3.4	3.5	3.5	1.8	2.1	2	8.7	9.2
198	3.7	2.9	3.2	3.1	1.8	2.1	2	7.6	8.3
199	3.5	2.7	3.3	2.9	1.8	2.1	1.9	7.5	8.7
200	3.6	2.6	3.1	2.8	1.9	2.2	2	7.5	8.5
201	3.8	3.5	4.1	3.7	2.1	2.1	2.1	9	9.9
202	3.8	3.5	3.8	3.6	2	2	2	8.8	9.7
203	3.4	3.1	3.6	3.3	2	2.4	2.2	8.7	9.6
204	3.5	3.1	3.6	3.3	2	2.5	2.1	8.7	10.1
205	3.7	3.3	4.1	3.6	2.4	2.8	2.5	9.5	11
206	3.7	3.2	3.9	3.5	2.3	2.7	2.4	9.3	10.7
207	3	2.5	3.4	2.8	1.6	2	1.7	6.8	8.7
208	3.1	2.6	3.2	2.7	1.6	1.8	1.6	6.7	7.9
209	3.4	2.8	3.2	3	2	2.2	2.1	7.6	8.5
210	3	2.7	3.2	2.9	1.9	2	2	7.6	8.2
211	3	2.7	3.3	3	1.8	2.1	1.9	7.5	8.4
212	3.5	3.4	4	3.7	2.3	2.6	2.5	9.8	11.3
213	3.4	2.7	3	2.9	1.8	2	1.9	7.3	8.1
214	3.2	2.6	2.9	2.7	1.8	1.8	1.8	7	7.7

(8) C.

	10b	11	12	13	14	I	II	III	IV
187	7.2	.5	23	18	2	63.5	59.2	18.1	2.14
188	7.2	.4	15	11	15	75	71.4	17.7	1.82
189	7.5	.3	18	13.5	6.5	72.6	70.8	18.5	1.36
190	6.9	.5	18	13	13.5	62.5	60.5	17.2	2.14
191	7.3	.7	21	17	8	65.6	59.5	17.9	3.12
192	7.5	.6	15.5	11	13	64.5	59.5	18.2	2.47
193	6.2	.5	16	12	18	67.3	61.7	17.4	2.08
194	7.7	.5	23	19	3	52.2	61	18.2	2
195	7.6	.2	18.5	13.5	11.5	64.1	60.3	18.1	.81
196	7.1	.2	10	6	20	66.7	62.5	19	1
197	6.9	.5	19	15	1.5	52.9	60	17.4	2.44
198	6.9	.1	15.5	10.5	20	62.1	65.6	17.4	.56
199	7	.2	26.5	21	9.5	64.8	64.6	20.2	1.93
200	6.9	.2	22.5	16.5	23	71.2	69.4	20.3	1.22
201	8.1	.8	32	26	3.5	59.4	51.9	21.8	4.16
202	8	.8	26.5	19.5	5	55.7	52.6	21.5	3.6
203	7.2	.6	21	17	2.5	64.5	65.3	17.8	2.57
204	7.6	.8	20	15	22	64.5	69.4	18.7	3.27
205	8.2	.5	18	13.5	8	72.7	67.1	18.3	2.11
206	8.1	.4	13.5	9	35.5	71.9	68.8	18.5	1.7
207	5.8	.2	10	6	0	64	58.8	16	1.33
208	6	.4	14	10	25	59.6	54.7	16.3	2.03
209	6.9	.3	18	13	9	71.4	68.8	19	1.55
210	6.8	.5	27.5	22	10	70.4	62.5	20.2	2.78
211	6.7	.3	14	11	24	66.7	63.6	20.3	1.86
212	8.6	1.1	19.5	15	33.5	67.6	65	20.9	4.15
213	6.6	.5	25	20	2	66.7	65	17.5	2.2
214	6.2	.1	14	10	18	70.6	62.1	16.4	.56

(9) A.

	1	1a	1b	2	2a	3	4	5	6
215	38.2	38.6	38.2	36.6	36.6	6.3	4	3.6	4.2
216	38.1	38.6	38	36.6	36.6	6.4	4.3	3.7	4.1
217	36	36.3	35.7	34.4	34.4	6.8	3.7	3.6	4.2
218	35.4	36	35.1	33.9	33.9	6.7	3.9	3.8	4.1
219	40.7	41	40	38.8	38.8	7.2	4.3	3.8	4.7
220	40.2	40.6	39.7	38.6	38.6	7.4	4.1	4	4.6
221	34.3	35	33.9	32.7	32.6	7.4	4.6	4.1	4.6
222	36.6	36.9	36.3	34.5	34.5	7	4.1	3.6	4.6
223	36.6	36.9	36.3	34.8	34.8	7.1	4.3	3.7	4.6
224	37.8	38.3	37.6	36	36	7.1	4.4	4	4.5
225	38.1	38.7	37.8	36.4	36.2	7.2	4.5	3.9	4.4
226	37.3	37.7	36.6	35.1	35.1	7.3	4.5	4	4.7
227	37.1	37.6	36.5	34.9	34.9	7.5	4.3	4.1	4.7
228	38.4	39	38	36.4	36.4	7.4	4.4	3.4	4.6
229	37.9	38.7	37.6	36	35.8	7	4.4	3.6	4.5
230	32.7	33.2	32.3	30.9	30.9	6.8	3.9	3.9	4.4
231	35.9	36.3	35.5	34	34	6.8	4	3.6	4.5
232	35.7	36.5	35.5	34.1	34.1	6.8	3.9	3.8	4.4
233	35.7	36.1	35.3	33.8	33.8	7.3	4.5	4.1	4.5
234	35.6	36.4	35.6	34	34	7.3	4.5	4.2	4.5
235	39.3	39.8	38.8	37.2	37.2	7.3	4.6	4.3	4.8
236	39.3	40	39	37.5	37.3	7.3	4.4	4	4.7
Average	38	38.6	37.7	36.3	36.3	6.9	4.3	3.9	4.5
Maximum	44.6	45.1	44.3	44.2	44.2	7.9	5.4	5	5.4
Minimum	31.6	32.1	31.6	30	30	5.2	3.3	2.6	2.9

(9) B.

	7	8	8a	8b	9	9a	9b	10	10a
215	3.1	2.5	3	2.8	1.7	1.9	1.7	6.9	7.7
216	3.1	2.4	2.8	2.6	1.7	1.9	1.7	6.8	7.5
217	3.2	2.5	3	2.7	1.9	2	1.9	7.4	8
218	3.2	2.6	3.1	2.8	1.8	2	1.9	7.4	8.1
219	3.5	3.5	3.6	3.6	2.6	2.6	2.6	9.9	10.3
220	3.4	3.6	3.4	3.7	2.6	2.6	2.6	10	9.9
221	3.8	3.1	3.7	3.1	2	2.3	2	8.4	9.5
222	3.5	3	3.4	3.1	1.9	2	2	7.9	8.6
223	3.5	3	3.4	3.1	1.9	2	2	7.9	8.5
224	3.2	2.8	3.3	3	2.3	2.3	2.2	8.1	8.9
225	3.4	2.8	3.4	3	2.2	2.3	2.2	8	8.9
226	3.5	3	3.6	3.1	2	2.5	2.1	8.1	9.8
227	3.7	2.9	3.4	3.1	2	2.4	2.2	8.2	9.3
228	3.6	3	3.5	3.2	2.3	2.4	2.3	8.5	9.6
229	3.6	3	3.7	3.4	2.2	2.2	2.2	8.6	9.6
230	3.1	2.7	3.2	2.8	1.7	2.2	1.8	7.6	8.6
231	3.3	2.6	3.3	2.6	2	2.2	2	7.7	8.6
232	3.2	2.6	3.1	2.6	1.8	2.2	1.8	7.5	8.5
233	3.6	3	3.6	3.1	2.1	2.4	2.1	8.1	9.8
234	3.6	3	3.7	3.1	2	2.4	2.1	8.1	9.7
235	3.5	2.7	3.1	2.8	2	1.9	2	7.4	8.2
236	3.6	2.8	3.2	2.9	1.9	1.9	1.9	7.5	8.4
Average	3.4	2.9	3.3	3.1	2	2.2	2.1	8.1	8.9
Maximum	4.1	4	4.3	4.1	2.9	3.2	3	11.1	11.5
Minimum	2.4	2.1	2.4	1.7	1.4	1.7	1.5	6.1	6.1

(9) C.

	10b	11	12	13	14	I	II	III	IV
215	6.2	.1	13.5	11	2	67.3	63.3	16.2	.5
216	6.1	.1	15	10.5	30	70.8	66.1	16	.51
217	6.4	.2	16	12.5	9	74	64.5	17.8	1.11
218	6.5	.2	19	14	27.5	69.2	62.9	18.2	1
219	7.6	.5	11.5	10	13	73.6	72.2	18.7	2.2
220	7.3	.3	9.5	6	22	72.2	75	18.2	1.36
221	7.6	.2	8	3.5	23.5	64.5	60.8	22	1.57
222	6.8	.6	18	14	13	61.7	57.4	18.6	2.83
223	6.8	.3	17.5	12.5	22	64.4	57.4	18.4	1.41
224	6.8	.3	14	10	13	83.6	68.2	18	1.6
225	7	.2	13	8.5	9.5	78.6	67.2	18.4	1.06
226	7.3	.4	15	12	16	67.8	69.4	19.4	2.07
227	7.1	.4	17	13	26	69	70.6	19.1	2.07
228	7.1	.3	18	14	22	76.7	67.1	18.5	1.44
229	7.6	.3	16	12	29	71.7	60.3	19.9	1.37
230	6.7	.6	28	22	7	64.2	68.3	20.5	3.03
231	6.9	.3	27	22.5	5	78.4	67.7	19.1	1.43
232	6.7	.2	15	12	17	69.2	69.4	18.8	.95
233	7.3	.3	20.5	17	3.5	70	66.7	20.3	1.48
234	7.3	.3	24	19.5	14	66.7	64.4	20.4	1.71
235	6.9	.1	13	10	3	73.6	61.3	17.6	.63
236	6.9	.2	15	12	20.5	66	59.4	17.6	1.26
Average	.7	.4	17	13	17	68.7	65.2	18	2.02
Maximum	8.9	1.2	32	26	55.5	101.6	86.2	24.9	5.06
Minimum	5.3	0	6	3.5	0	37.7	50	7.5	0