Zustande herzustellen, — wobei natürlich die Säurekomponenten auch mit Berücksichtigung derjenigen der Naturprodukte gewählt werden müssen —, ihre chemischen, physikalischen und physiologischen Eigenschaften zu untersuchen und die Eigenschaften isomerer Repräsentanten der $\alpha$- und $\beta$-Reihe zu vergleichen. Es ist wohl kaum zweifelhaft, dass derartige Untersuchungen in physiologisch-chemischer Hinsicht zu interessanten Resultaten führen werden, umsomehr, da auch von anderen Basen als Cholin oder Colamin abgeleitete Phosphatide in die Untersuchungen einbezogen werden können.

Diese Abhandlung bezweckt nur auf dies alles die Aufmerksamkeit hinzulenken, auf neue Möglichkeiten für die Synthese der hier in Frage stehenden Substanzen hinzuweisen und — für soweit dies tunlich ist — das betreffende Gebiet für uns zu reservieren.

§ 5. Selbstverständlich wird der Wunsch rege, auch *Lysophosphatidsäuren* und *Lysophosphatide* von völlig bekannter Konstitution in die soeben angedeuteten mehr allgemeinen Untersuchungen einbeziehen zu können. Bei Verwendung tritylierter Glycerolderivate als Ausgangsmaterialen liegen in dieser Richtung fraglos Möglichkeiten vor. Wir hoffen, hierauf später zurückzukommen.

*Rotterdam,* Dezember 1937.

*Laboratorium der Niederländischen Handels-Hochschule.*

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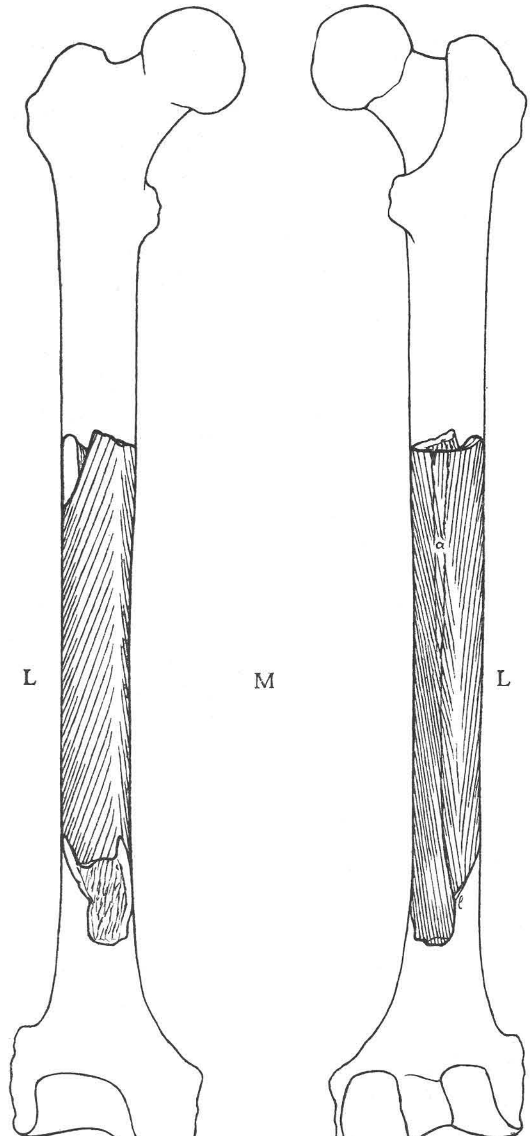
**Anatomy.** — *The osteone arrangement of the thigh-bone compacta of Man identical with that, first found, of* Pithecanthropus. By EUG. DUBOIS.

(Communicated at the meeting of November 27, 1937.)

The evidence of the existence, on the six hitherto acquired thigh-bones of *Pithecanthropus,* of certain distinctly deviating external features, common to all of them, in so far as these features fall within the limits of the preserved parts, "firmly established that ""the Trinil femur"" was not quite of the human, but of a different type and belonged to a different organism". This is a conclusion which harmonizes with the result, in this respect, of my researches on the cephalization.

Further evidence of difference from the human femur appeared to be given, seemingly, by the Fifth fossil Trinil femur, clearly showing an osteone arrangement of the compact bone substance, which strikingly deviates from that generally believed, though erroneously as now turns out, to exist in Man. I may here refer to the description, the plates and the diagrams of my paper [1]) communicated at the meeting of February 24, 1934, adding, however, a few words concerning, firstly, the fossilization




Diagrams of the fifth *Pithecanthropus* femur, from before (left diagram) and from behind (right diagram). The fragmental shaft located in the outlined entire right femur $^1/_3$. *M* medial side, *L* lateral side, *a* linea aspera, *l* its divergent Labium laterale [2]).

and a subsequent process, which made so clearly perceptible the osteone

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[1]) New evidence of the distinct organization of Pithecanthropus. Proc. Royal Acad. Amsterdam, **37**, 139—145 (1934). With 2 Plates and 2 diagrams.

[2]) The maximum of obliquity is 15°, (erroneously in the quoted paper 20°).

arrangement, that it enabled Professor BOK to make the beautiful photographs reproduced in the two Plates which illustrate the quoted paper. It was undoubtedly the action of sulphuric acid which corroded the perfectly fossilized femur *V* and abraded the superficial layer of the compacta. At the same time it caused a *bas-relief* sculpture, composed of, principally, two systems of fine grooving or furrowing, together with coarse unevennesses [1]), of different direction, both principal systems oblique with respect to the long axis of the shaft, the one diverging from the other anteriorly and converging posteriorly, the two separated, anteriorly and posteriorly, by a narrow and nearly vertical intermediate zone. The sculpture otherwise envelopes the shaft completely. Numerous very thin white stripes, the Haversian canals filled up, probably with calcite, are seen running parallel to the corrosional grooves. More than one, even quite a number of Haversian canals may belong to one groove. However, the corrosional fine grooves, as well as the thin natural canals, indicate the directions of the osteones.

I may, further, remind of the obviousness that this striking osteone arrangement was caused by the tension stresses corresponding to the action of the different parts of the musculus quadriceps femoris, especially the vastus lateralis and the vastus medialis, with the vastus intermedius. It is the exact reverse of the opposite muscle fibre arrangement. To the rectus femoris evidently belongs, in the right diagram, the posterior narrow intermediate strip, laterally from the crista femoris, about the middle of the shaft, when it was complete. It may be remarked that the osteone arrangement system belonging, in the same diagram, to the vastus lateralis, transgresses the lateral limit of the crista femoris. In the left diagram the intermediate partition line is the reverse of the opposite crista femoris and its labium laterale; below, therefore, it runs near to the medial side of the femur shaft.

This structure of the femur of *Pithecanthropus* seemed, indeed, very different from the human conditions as they were in the current opinion. Therefore, in the quoted paper of 1934, I wrote (p. 143):

"The histological conditions in the compacta of the femur shaft in Man differ greatly from those in *Pithecanthropus*. The well-known regular p e r p e n d i c u l a r arrangement of the osteones, parallel to the axis of the shaft, requires no description. Such a regular axial structure is also apparent in the direction of the lamellae and trabeculae of the cancellous tissue at the lower end of the human femur. I have made sure, moreover, by means of ultra-violet rays, in the Laboratory of Professor L. VAN ITALLIE, that there exists no other obliquity in the structure of the human (European, Javanese) femur. In Anthropomorphous Apes (Chimpanzee,

[1]) The grooves are in reality generally very much finer than would appear from the unevennesses in the microphotographs ($^5/_1$) which were not adjusted to the surface of the fossil bone, but to the Haversian canals, on a somewhat deeper level. Something of the real condition is to be seen, though faintly, on the right-hand side of Plate *I* and *II* in the quoted paper.

PLATE I

Right Femur *1*. $^1/_1$. Posteriorly medial view, showing reverse of the opposite vastus lateralis muscle.

Orang-outan, Gibbons) there is some rough indication of a certain diagonal structural deviation in the compacta of the lower end of the femur, of the same kind as that in the cancellous tissue, a long time ago (1904) recognized by O. WALKHOFF. But the one and the other are as different from the condition in *Pithecanthropus* as from that in Man. Thus, morphologically, *Pithecanthropus*, in this respect, is well distinct from those two families of Primates."

However, I was not quite satisfied, and thought of a way to check more rigorously the current opinion on the structure of the compacta of the human femur, properly dating from the time of HERMANN VON MEYER's publication of 1867, on "*Die Architektur der Spongiosa*" [1]), in which he said, that, self-evidently, the compacta must have an architecture answering to a condensed spongiosa. Though the "trajectorial structure" of the substantia spongiosa has been intensively studied since VON MEYER's remarkable discovery of functionality in the arrangement of that substance, it was not before 1925 that an investigation into the macroscopical structure of the substantia compacta was actually carried out. A. BENNINGHOFF then applied a method, which had its origin in observations of DUPUYTREN (1836) and MALGAIGNE (1859), and was applied, in researches on the course of the fibres in the cutis, by LANGER (1862), and on the structure of articular cartilage by HULTKRANTZ (1898), and found that, the same as pricks in the (dead) cutis and articular cartilage, pricks in the superficially decalcified bone compacta, made with a round awl (previously dipped in a stain) do not cause (stained) round h o l e s, but (stained) small s p l i t s. This obviously is, and was in the other cases, a consequence of stresses resulting from some degree of external desiccation. In this way BENNINGHOFF [2]) (1925) found ranges of such splits, which compose "split lines", to be parallel to the direction of the osteones, and consequently of the greatest resistance to tension and pressure. He examined especially flat bones. Having first put to the test of this method the long bones, he saw that almost generally the split lines on the shaft run lengthwise, and, after removal of the external layers of the compacta, the general lamellae, it appeared to him, that in the deeper layers the direction of the osteones, as perceptible with the naked eye, remains parallel to the long axis of the shaft. He adds, however, that he did not succeed in isolating the osteones on longer stretches than 3 to 4 cm, and did not take special pains in that respect.

Again, HENCKEL [3]) (1931) confined his researches on the structure of the

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1) HERMANN VON MEYER, Die Architektur der Spongiosa. Reichert und du Bois Reymond's Archiv für Anatomie und Physiologie (1867).

2) A. BENNINGHOFF, Spaltlinien am Knochen, eine Methode zur Ermittlung der Architektur platter Knochen. Verhandl. Anatom. Gesellsch., pp. 189—206 (1925).

3) K. O. HENCKEL, Vergleichend-anatomische Untersuchungen über die Struktur der Knochenkompakta nach der Spaltlinienmethode. Gegenbaurs morphol. Jahrbuch, **66**, 22—45. With two plates (1931).

bone compacta, by means of the split line method, to the superficial layer of the compacta. Concerning the human thigh-bone, he figures the upper part and says: "Am Schaft des Femur ziehen die Spaltlinien in der Längsrichtung des Knochens, wobei im Bereich der Linea aspera die Spaltlinien in schräger Richtung auf die Erhebung zu verlaufen können (spacing from myself) [1]. Im proximalen Abschnitt (vgl. Abbildung 19) ziehen die vom Schaft herkommenden Spaltlinien zum Teil zum Trochanter major, zum Teil zum Trochanter minor."

I regret that not until last summer I became acquainted with those publications on the structure of the compacta, especially because the researches only referred to the superficial layer, and thus the papers contained at the same time the unspoken information that our knowledge of the structure of the compacta as a whole, namely including the deeper layers, particularly in the case of the human femur, is not founded on direct observation, but on conclusions from the trajectorial structure of the spongiosa. BENNINGHOFF [2] (1927), in another paper, in extending into the compacta the trajectorial stress lines of the spongiosa of the Dolphin (*Delphinus delphis*) radius, after ROUX' incomplete drawing, emphasizes, rightly in my opinion, that compacta and spongiosa are but parts of one system of "substantiated" stress lines. Evidently in this case, the same as in the case of the humerus of the small White Whale (*Delphinapterus leucas*), of which R. SCHMIDT [3] photographed the sagittal section, the beautiful "substantiated" trajectorial stress lines cannot but be caused by muscle action. However, apparently, this did not induce ROUX, SCHMIDT and BENNINGHOFF to reconsider the case of the human thigh-bone.

It was fatal to the growth of this important branch of biological science that the first discovery of what afterwards was called *funktionelle Anpassung* in the spongiosa of the upper end of the human femur had a bearing on the erect stature. This induced the anatomist HERMANN VON MEYER readily to adopt from CARL CULMANN, great builder of iron bridges and founder of graphostatics, the ideas of the crane with trajectories, and the "architecture" in bone substance: as subjects of statics. This view, from such an authority, would prevail till the present time, hampering the development of bio-dynamics. But about 1867 the opposition against vitalistic views was at its climax, and thirty years before, the description of the experiments of the brothers WEBER,

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1) Probably this relates to cases of somewhat deeper decalcifying; the oblique convergent directions may then have been those of more internal compacta layers. The same was possibly the case, in the proximal part of the shaft, with some of the figured oblique split lines, which may have reached the deeper compacta layers.

2) A. BENNINGHOFF, Ueber die Anpassung der Knochenkompakta an geänderte Beanspruchungen. Anatomischer Anzeiger, **63**, 289—299 (1927).

3) R. SCHMIDT, Vergleichend-anatomische Studien über den mechanischen Bau der Knochen und seine Vererbung. Zeitschrift für wissensch. Zoologie. (Kölliker u. Ehlers), **65**, 65—111. With two plates (1899).

Proximal

Distal

Part of shaft of femur *1*, $^5/_1$. Medial posterior view. Reverses of the opposite vastus lateralis muscle (on the left side), and vastus medialis muscle (on the right side).

(WILHELM the physicist and EDUARD the physiologist), described in their *"Mechanik der menschlichen Gehwerkzeuge"*, had made a lasting impression on the minds of a great number of biologists. Apparently, the human upright stature and gait were, indeed, almost mere mechanism, but minimal performance.

However, in a living organism, muscle force is very much greater than mere gravity. *In casu*, the physiological section of the human musculus quadriceps femoris corresponds to a total of contraction forces of about twenty times, and cooperation of the four parts of this, by far the strongest human muscle, developes a force of at least four times the dead body weight.

All these considerations induced me, during the last summer, to check the current idea on the structure of the human femur compacta. What nature did with the fossil Trinil femur *V*, remove the superficial layer of the compacta by corrosion, I tried first on a macerated human thigh-bone, by abrading its general lamellae with a rasp and a series of emery papers, from very coarse to very fine, to a depth of about one millimeter, and then, after decalcifying, applying the split line method. It appeared however, that this method was in fact inadequate to reveal such a subtle structure as that made perceptible on the fossil femur by nature. I then thought that, perhaps, more might directly be expected from thigh-bones which had been, during a long time, in conditions, to some degree comparable with those which obtain in fossilization processes.

In such conditions had been a number of human thigh-bones from an old burial-place in the Valken-Bulwark (now called Rijnsburger Bulwark) at Leyden, used in periods of plague epidemics, dating from years between 1752 and 1875. There these bones remained, in the clayey soil of the Holland lowland, during a lapse of time from a minimum of 61 to a maximum of 184 years. The ground water level has been much lowered in that time. It did not surprise me, that many of the bones, in these circumstances, showed a brownish impregnation, the nature of which is not yet investigated. Probably it is impregnating limonite (hydrous ferric oxide).

After the removal, in the same way as described above from the macerated thigh-bone, of a superficial layer of the shaft of seven of these thigh-bones, of which number 1, 2, 3, 6 and 7 are from the right side, number 4 and 5 from the left side, it appeared that on all of them the osteone arrangement is identical with that of the fossil *Pithecanthropus* femur *V*. Consequently it needs no further description.

The general direction of the Haversian canals is, in each system, distinctly visible on the seven thigh-bones, all of them, by means of a magnifier. But according as the brown tinted impregnated parts increase and become darker, in the series of the numbers 2, 4, 3, 5, 1, 7, 6, the Haversian canals become less perceptible. In places, however, the impregnation painted the osteone arrangement in a similar way as the corrosion sculptured the grooves or furrows on the fossil Trinil femora *II* to *VI*, most beautifully on femur *V*. In this manner a reddish white impregnation has made the osteone arrangement surprisingly perceptible on the thigh-bone Nr. *1*, by differential impregnation of the lamellar substance, in an analogous way as on the fossil femur by differential corrosion. Therefore there is a certain amount of similarity between the impregnated thigh-bone *1* of Table *I* and the corroded fossil femur, in so far as regards the grooving or furrowing.

A photograph of this thigh-bone, natural size, ("the whole length in the natural position" being 452 mm), [1]) viewed from behind and medially, in order to show a part in full length of the clear reverse of the vastus lateralis muscle, the most powerful part of the musculus quadriceps femoris, is reproduced in Plate *I*. Plate *II* is a reproduction of a microphotograph, 5 × nat. size, of a part about 3 cm above the middle of the shaft's length. It shows the convergence of the reverses of the vastus lateralis and vastus medialis muscles.

Of course the now found structural and functional similarity of Man and *Pithecanthropus* is new evidence of r e l a t i o n s h i p between the two. Not, however, of organismal i d e n t i t y, as it, perhaps, will appear to narrow morphology, for, the distinctness of *Pithecanthropus* is firmly established by certain constant external characters of the thigh-bone, and, above-all, by that determinant character, the cephalization level, which in *Pithecanthropus* is one degree below that in Man. An analogous case we meet with in *Australopithecus transvaalensis*, the teeth of which extraordinary being resemble closely those of modern Man; its cephalization level, however, compels to place this species with Anthropoid Apes.

I am much indebted to Professor WOERDEMAN for the great care he took, in his Laboratory for Anatomy and Embryology of Amsterdam University, to represent, by clear photographs, all that is perceptible of the osteone arrangement on this Leyden thigh-bone *1*. From the above descriptions, of those burial-place thigh-bones and the fossil Trinil-femur *V*, the reader will be convinced, that in the photographs, which are reproduced in the two plates illustrating this paper, Professor WOERDEMAN did, indeed, succeed very well.

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[1]) I may remind of the same "length" of *Pithecanthropus erectus 1* being 455 mm.