Palaeontology. — *"On the Principal Characters of the Cranium and the Brain, the Mandible and the Teeth of Pithecanthropus Erectus"*. By Prof. EUG. DUBOIS.

(Summary of the communications at the meetings of May 26, and November 24, 1923, nearly identically summarized in the "Verslag" of the meeting of February 23, 1924) [1]).

Before the morphological characters of the fossil remains of this Primate are discussed, a few remarks may be made about the state of perfect **mineralization** in which they are. This state is entirely different from that of the oldest of the human remains known. Their specific gravity, like that of the bones of the other mammals which were dug up with them at Trinil (which bones have the same outward appearance), has risen to about 2.7, an increase of about 35 % compared with dry fresh bony substance. That of the Piltdown-man (Eoanthropus) differs very little, if at all, from the latter, according to the accurate determination of its specific gravity [2]). Also the mandible of Mauer and the bones of the fossil man of La Chapelle-aux-Saints have become only comparatively little heavier. On the other hand the specific gravity of the bony substance of the fossil mammals from the late-pliocene clay of Tegelen (with Elephas meriodionalis, Rhinoceros etruscus, Equus stenonis, pliocene Deer, Trogontherium cuvieri, and a pliocene flora), though petrified in another way, viz. silicified, is equal to that of the bones of Trinil. In the fossil bones of the Neandertal man of Spy a not unimportant quantity of glutinous substance has remained; in the bones of Trinil, on the other hand, only traces of humus substances are present, which give them a chocolate-brown colour.

According to the analysis of the late Prof. J. M. VAN BEMMELEN both phosphate and carbonate of calcium have taken the place of the ossein, and they contain fluorium in the quantity which, according to AD. CARNOT'S investigations, is characteristic of fossil bones of the Pliocene. The particular pseudomorphism known as mineralization, petrifaction or fossilization, has very strongly affected the bones

[1]) The author proposes before long to discuss the subjects of these communications more at length in a memoir elucidated by illustrations.

[2]) Quarterly Journal of the Geological Society, Vol. 69, p. 121. London 1913.

of Trinil. Their great antiquity appears also from this that calcite and pyrites have crystallized in many cavities and canals in the bones.

Though these physical and chemical properties with the character of the mammal fauna, stamp the remains of Pithecanthropus as pliocene, this says little as criterion of its phylogenetic significance, given the simultaneous existence of allied forms at different stages of development, observed everywhere.

Decisive are here the **morphological characters** of Pithecanthropus. In the first place those characters of the skull which can be recognized at the calvarium from the Kendeng-layers of Trinil, and of the brain in so far as these can be judged from the endocranial cast of the calvarium; further the morphological characters of the mandible and the teeth, from a fragment found near Kedung Brubus, in the same Kendeng-layers, and the three teeth dug up at Trinil; and finally the morphological characters of the femur excavated there.

The morphological investigation of the cranium is restricted or hampered by three circumstances: first that only the upper part of the calvaria as calotte or calvarium has been preserved; secondly that the outer surface has been greatly corroded by sulphuric acid, formed from pyrites in the volcanic tufa; thirdly that the cranium has been deformed in a natural way (through trigonocephalism, though in a small degree).

These circumstances have not seldom led to erroneous conclusions in the study of the plaster cast. At the fossil calvarium itself at least the principal morphological characters can be clearly observed.

At the plaster cast it cannot be seen in every detail to what extension the calvaria has been preserved, especially not at the frontal border and in the temporal region. The situation of the glabella-point and of the asterion, and in approximation of missing parts, as the meatus acusticus, the processus mastoideus, can therefore only be determined at the fossil itself. In virtue of this and on account of some loss of substance at the inion, the real maximum cranial length may be put at 184 mm., though the directly measurable length is only 180.5 mm.

Particularly, however, about the original state of the external surface of the calvaria the fossil alone can give an accurate idea. It must have been smooth on the whole, about as at the skull of a small gibbon species, because there are nowhere traces present of distinct ridges, still less of crests, except the apparently perfectly gibbonlike crista supramastoidea. Between intact spots, corresponding to which also the endocranial cavity reaches it greatest width, the

greatest cranial breadth, 131 mm., can be measured. Hence the length-breadth index is 71.2. It may also be mentioned here that the calvarial height above the glabella-inion line (SCHWALBE's "Calottenhöhe") is 61 mm.

On account of much loss of substance on the left side the post-orbital breadth (constriction) can also only be judged from the fossil remain itself. It is 87 mm., the original (true) breadth must, however, have been at least 91 mm. The fronto-biorbital index (SCHWALBE), i.e. its ratio to the external orbital facial breadth, which latter I estimate at 115 mm. as a minimum, is at most 79. In a cranium of a Hylobates agilis resembling that of Pithecanthropus in many respects, this index is 78.4. The post-orbital length index (SCHWALBE) is 25.5, the distance between the orbital constriction and the bregma-transversal being 47 mm. This index is 25 at the same cranium of Hylobates agilis. The whole pre-cerebral part of the frontal bone is hylobatoid, like the rest.

The keel-shaped elevation of the external surface of the frontal bone is about the same as that in the original state, but the rhombic eminence at its upper end, whose apex coincides with the bregma, was much less pronounced at the intact cranium than at the corroded calvarium. The trigonocephalism, which was the cause that the frontal part of the skull is comparatively narrow, the temporal part comparatively broad, is caused in Man by early fusion of the two frontalia; it may be assumed that also in the skull of Pithecanthropus this premature fusion has given rise to the existence of the torus frontalis medianus, in favour of which also plead the extraordinarily strong impressions of the cerebral convolutions at the inner surface of the frontal bone. Hence the great breadth of the temporal part of the skull is not to be considered, as ELLIOT SMITH asserts, as a consequence of spontaneous stronger development of the temporal cerebral lobe.

The shortest distance between the two temporal lines was probably 85 mm., the ratio to the cranial breadth is the same as that of the small gibbon species.

It is seen that to the sagittal arc-length of the cranial vault the frontal bone contributes 100 mm., the parietal bone 90 mm., and the upper part of the tabular portion of the occipital bone 45 mm. This is an entirely different ratio between the two first divisions of the vault from that in Homo sapiens and Homo neandertalensis, where the parietal arc is longer than, or equally long as, the frontal arc. In the Hylobatidae, on the other hand, the parietal bone is much shorter in comparison with the frontal arc, than in Pithecanthropus. The latter's fronto-parietal index is 90, that of the large

gibbon genus, Symphalangus, 53 on an average, and that of the small gibbon species has an average value of 42. The relative length of the frontal squama diminishes with increasing size of the body, in consequence of the diminution that this entails of the ratio between the volumes of the orbita (with the eye) and the cranial cavity (with the brain). Besides, in Pithecanthropus the cranial cavity has become more spacious mostly in another way than through the greater size of the body.

The lower part of the tabular portion of the occipital bone, the pars nuchalis, bends downwards and forwards at an apparently not very obtuse angle. But this obtuse angle was much larger at the intact skull, because at the fossil calvarium the loss of substance greatly increases towards the edge of the fragment, so that this edge only still consists in the knife-like lamina interna. In the intact state of the skull Pithecanthropus resembled the Hylobatidae in the steepness of the planum nuchale.

The torus occipitalis presents the closest resemblance with that of Symphalangus syndactylus.

In the view of the cranial vault from below the very spacious and largely communicating right and left sinus frontales may be recognised in their full width and depth. Together they have a width of 55 mm.; their greatest depth (measured from the front backwards) is 23 mm. The maximum endocranial length between the frontal and the occipital poles amounts to 153 mm. on the left, to 155 mm. on the right side. The maximum endocranial breadth is 124 mm. The apex of the endocranial cavity is above this transversalis, to a height of 58 mm. This transversalis lies about in the transversal plane of the right frontal pole and the upper edge of the right sulcus transversus, to which plane the capacity of the calvarium was measured. Within the whole reach of the frontalis its inner surface shows very strong impressions of the cerebral convolutions, undoubtedly a consequence of premature union of the two halves of the bone. The cerebral impressions and the likewise very strong grooves of the arteria meningea medea are most clearly to be seen at the endocranial cast, reproducing the positive of the cerebral surface. In the reach of the parietalia and of the attached parts of the temporalia there are hardly traces to be seen of the impressiones digitatae and juga cerebralia, with the exception of the jugum sulci centralis and the jugum sulci intraparietalis. There is also a strong jugum sulci lunati, lying immediately behind the sutura lambdoidea. (In the Hylobatidae and the Chimpanzee this jugum lies as a rule immediately before the suture).

Of that process in the cranial cavity chiefly formed by the lesser

wing of the sphenoid, which in the brain corresponds to the fissura Sylvii, a considerable piece has been preserved especially on the right side. Present is also a powerful crista occipitalis interna, which possession distinguishes Pithecanthropus from the Hylobatidae, which have there a wide groove, as impression of their round, barer vermis cerebelli, and agrees with the large Simiidae and Man. The endinion lies 26 mm. lower than the inion externum. The sulcus sagittalis, the torcular Herophili, and the right sulcus transversus are wide and deep. With respect to the latter sulcus the parieto-mastoid suture lies exactly the same as in Hylobates. Also as regards the situation of the internal asterion Pithecanthropus agrees entirely with Hylobates. For the postasterial index (the ratio of the distance between the asterion and the occipital pole and the endocranial length) I find 15,5 in Pithecanthropus, 15,8 in Hylobates, and a mean value of 24 in human skulls of different races.

The form of the skull of Pithecanthropus is on the whole not human; nor is it a transition of any type of manlike apes to the human type. The agreement with the anthropoid cranial type, particularly that of the small gibbon species, of the genus Hylobates, may on the other hand be called perfect, taking into consideration the inevitable deviation in the proportions in consequence of the ratio of the volume of the brain and the eye varying with the increasing bulk and cephalisation. For with increasing bulk the eye increases somewhat less in volume than the brain, and by the much higher cephalisation of Pithecanthropus the brain was besides enlarged far beyond the homoneuric ratio. The fossil cranium is not more highly arched, has no less receding forehead, and the pre-cerebral part of the frontalis projects equally far forward as in those Apes. The constriction ("Einschnürung") behind the orbitae is also perfectly pithecoid in its depth and its situation at a greater distance from the front border of the skull; so is the place where the external auditory meatus must have been, and the form of the crista supramastoidea. Perfectly pithecoid was further the shape of the torus occipitalis transversus and the value of the angle at which the nuchal plate of the occipital bone bends foreward and downward. In all these points Pithecanthropus is distinguished no less strongly than the Anthropoid Apes from the Neandertal Man. From the latter character of the fossil skull it may be derived that also the condyles of the occipital bone were placed in the same way as at the skull, so that the head was not equipoised on the spinal column as in modern Man, but was carried by strong nuchal muscles and ligaments as in Apes. It is not to be seen by the structure of the skull that Pithecanthropus deserves the name of

erectus, assigned to him on account of the features of the femur. This is, however, to be derived from a character of his brain and another of his mandible still to be discussed.

It is certain that the erect posture of the body, which clearly appears from the shape of the femur, was not such a perfect one as in Man; the correlation, at least, did not extend to the skull.

Nor can the skull, however, have belonged to an Anthropoid Ape, because the relatively very large skull as regards shape presents a close, nay striking resemblance with the skull of a small Hylobates-species, the smallest of the Anthropoid Apes, whereas judging not only from the femur and the molar teeth, but also from the skull itself, Pithecanthropus must have surpassed the size of a large chimpanzee, and very much that of a middle-sized man. Those smallest Manlike Apes distinguish themselves especially by their large neurocranium in the proportion of their splanchnocranium, the facial part of the skull. This is a consequence of the law governing the relation between the quantity of the brain and the bulk of the body in closely allied species. Small species have in general larger brains in comparison with their body weight than large ones of the same genus, sometimes also of the same family, in general than large homoneuric species (species with the same organisation of the nervous system). Judging by the linear dimensions, and as will appear further, by the cranial capacity, Pithecanthropus *as an Anthropoid Ape* would have been a giant of about 300 kg. weight, much larger than the heaviest gorilla. But Pithecanthropus was *not* such a giant. This appears not only from the dimensions of the femur, but also in the skull from the great distance of the temporal line, the boundary of the surface origin of the musculus temporalis from the median line, an indication that this masticatory muscle was weak with respect to the size of the neurocranium, though in such a gigantic Anthropoid Ape as Pithecanthropus then must have been, it would have had on the contrary a comparatively much larger area of origin, to find sufficient place at the then *relatively* small neurocranium. We may refer to the cranial crests of large male gorillas and orang-utans.

That the fossil skull bears such a striking resemblance to that of Hylobates, this dwarfish genus among the Anthropoid Apes, does not, therefore, compel us to class Pithecanthropus for this reason among this family, but it also gives support to the view that the Hylobatidae are actually to be considered as genuine and then the most primitive Manlike Apes, though such as are particularly specialized by their long arms and sabre-shaped canine teeth.

The most important difference between the brain of the Hominidae and that of the Simiidae, the Anthropoid Apes, consisting in the difference of volume, it is very desirable to know the **cranial capacity** of Pithecanthropus. The volume of the space in which the greater part of the cerebral hemispheres was contained, can be accurately measured with water up to a certain morphological limit [1]) in the calvarium, this having been made watertight. A volume was found of 570 cm³. In order to calculate the whole capacity from this part, the ratio of morphologically the same part to the whole capacity was determined in skulls of apes which resemble the skull of Pithecanthropus as much as possible. In general this ratio lies in skulls of apes very near 1 : 1.6. In human skulls of different races 1 : 1.4 was found on an average. In the skull of a Hylobates agilis, the shape and structure of which closely resembles the fossil skull, this ratio is 1 : 1.56. Taking small morphological differences into account, as particularly the much greater impressions which the orbitae make in that upper cranial part in Hylobates, the cranial capacity of Pithecanthropus can be calculated in approximation from this ratio at 900 cm³. This calculated capacity can certainly not depart greatly from reality. Besides, it may be considered to be about the mean of the species, as will appear further below. It may be assumed that with equal body weight Pithecanthropus possessed double the brain quantity of the Anthropoid Apes.

In its side view (norma lateralis) the **endocranial cast** presents a striking resemblance with the endocranial cast of a small Hylobates-species reproduced at the same size; thus also in the steep position of the endocranial planum nuchale. The only difference of importance consists in the much smaller impression which the orbitae make in the cerebral hemispheres than in Hylobates (where there is present a very pronounced "bec encéphalique" = rostrum orbitale, ethmoidale, or cerebrale), as a consequence partly (about $^1/_4$ of the calculated surface dimension) of the circumstance discussed before, that with increasing body-weight the eye, according to a definite law, is enlarged less than the brain, but especially (for about $^3/_4$ of the calculated surface dimension) that in Pithecanthropus the latter has double the volume of the brain of an Anthropoid Ape of the same bulk. Accordingly this difference does not entail another brain development.

There is on the other hand a great difference — and a difference of great importance — between the profile of the endocranial cast

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[1]) The transversal plane described in These Proceedings Vol. XXIII, (1921), p. 1272.

and that of the Neandertal Man of La Chapelle-aux-Saints. Though in consequence of its comparatively small height this seems more simean than that of Homo sapiens, also this human brain profile is seen to rise considerably above that of Pithecanthropus and Hylobates. From the front to the occiput, but the greatest difference, both in Homo neandertalensis and in Homo sapiens, is in the parietal region, near which apex the upper end of the sulcus centralis is situated. Hence the human brain may be called **macrotactile** in the highest degree, as occupying the highest stage of the development on the tactilomotive basis of the central gyri of the cerebral hemispheres characteristic of the Primates. Undoubtedly because the hand, the unequalled tactile organ and the most efficacious instrument of the entire animal world, reaches its highest perfection in Man.

The varying ratio of the size of the brain and the eyes may also account for the displacement of the bregma-point in a frontal direction, from Hylobates to Pithecanthropus, and from the latter to Homo neandertalensis, the lambda-point continuing to occupy about the same place in the side view outlines. The increasing size of the parietal bone appearing from this and its encroaching on the frontal bone, is apparently only a consequence of the orbital impression in the frontal lobe of the brain which becomes relatively smaller, and extends therefore less far backwards.

In Pithecanthropus the bregma-point lies about 12 mm. before the sulcus centralis of the brain, but still considerably behind the sulcus praecentralis superior. Just as in the Hylobatidae also the upper part of the coronal suture lies *behind* the sulcus praecentralis superior, in contrast with the large Anthropoid Apes and with Man, in which latter the crown suture is situated on an average from 2 to 3 cm. *before* the sulcus praecentralis.

Hence the coronal suture may be said to rise steeper and steeper with increasing size of the body; in the Hylobatidae and Pithecanthropus this is, however, attended with only slight displacement of the suture with respect to the gyrus centralis anterior, whereas this displacement is very considerable in the large Anthropoids and in Man.

That at least the displacement of the sulcus centralis (which is certainly a cytotectonic and physiological boundary line at the cerebral surface of the Primates) may be accounted for by the ratio of the size of the eye and the brain varying with the size of the body, is proved by the fact that the ratio of the parts of the surface of the brain lying before and behind this sulcus remains the same in

Pithecanthropus erectus and Hylobates agilis, viz. 1:1.73, measured to morphologically the same transversal plane.

In the frontal region of the cerebral hemispheres the gyri can be very clearly distinguished at the endocranial cast, as was already said above. They are slightly less simple on the left side than on the right, where they have also been preserved over a somewhat larger extent. For an immediate orientation the central and precentral sulci and the Sylvian fissure can at once be easily recognized.

Most conspicuous, to the front, is, on the right side, the **sulcus frontalis inferior,** as clear and unmistakable as in any human hemisphere, but in the simplest form, which it presents shortly before birth.

It has the shape of a ϧ lying almost on its side, the lower half of which encompasses a strong front branch of the Sylvian fissure. On comparison of this endocranial cast with endocranial casts of Chimpanzee, Gorilla, and Gibbons the validity of the interpretation of CHUDZINSKY, EBERSTALLER, HERVÉ, and WALDEYER appears with the greatest clearness, according to which the sulcus frontalis inferior of Man is homologous with the sulcus fronto-orbitalis of the Apes and the microcephalics, and then also the sulcus principalis or rectus of the Apes homologous with the sulcus frontalis medius plus fronto-marginalis (WERNICKE) of Man. In consequence of the greater increase of the brain volume compared with the eye, the sulcus fronto-orbitalis is seen to shift from the orbital to the lateral surface of the hemisphere from Hylobates to Chimpanzee (and Gorilla) for a great part, and to Pithecanthropus entirely. The cerebral convolution lying under and behind the sulcus fronto-orbitalis of the Apes is, therefore, the gyrus frontalis inferior. The conclusive establishment of these homologies is certainly the most important fact taught us by the unequalled endocranial cast of the Trinil calvarium. We meet, therefore, already with perfectly human forms in the frontal cerebral gyri of Pithecanthropus, and these forms are fundamentally the same as those possessed by the Hylobatidae, which we may admit to resemble the general ancestor of the Simiidae or Manlike Apes, notwithstanding their specialized features. The fundamental plan of the human brain thus evidently dates from the primitive simian one.

The two knees or genua of the sulcus centralis, so characteristic of Manlike Apes and constantly occurring, the upper or cruro-brachial and the lower or brachio-facial genu, physiological cortex boundaries according to SHERRINGTON, are also met with in Pithecanthropus,

and here the great length of the motor cortex region for the leg, at the expense of that for the arm, suggest a human gait and posture of body. For the rest the brain of Pithecantropus is not distinguished qualitatively, only quantitatively, from that of the Anthropoid Apes.

The **double brain quantity** (for equal bulk), is the most important characteristic that distinguishes Pithecantropus from the Anthropoid Apes, though in this respect it is still far inferior to Man, who (calculated for equal body weight) possesses four times the brain quantity of the latter. The laws of the relation between the weight of brain and body of related animal genera also teach that a higher organisation is obtained by a doubling of the whole or a very large part — the half — of the brain quantity (calculated for equal body-weights), evidently by cell-division, and resulting in a twofold, fourfold, or a sesquialteral, threefold, sixfold increase.

The same doubling of the whole brain quantity as from the simian level to that of Pithecanthropus and from Pithecanthropus to Man is found in the American ape genera Callithrix to Saimiri and Saimiri to Cebus, the generalized Ungulate Tragulus to the specialized modern types of Ruminantia, Mus to Lepus, Putorius to Mustela, Sorex to Talpa. In the same quadruple relation as Man and the Manlike Apes are Cebus (also Ateles) and Callithrix, Tupaia and Centetes. The Simiidae have once and a half times the brain quantity of the Cynopithecidae. Sciurus has the triple brain quantity of Mus, and the Megachiroptera the triple of the Microchiroptera, the same as Pithecanthropus in relation to the Cynopithecidae. Elephas has the sixfold quantity (always calculated for the same body-weight) of Procavia and Moeritherium. In the same relation is Man to the Cynopithecidae.

It seems to me that it is evident, at least, from all this that Man and Pithecanthropus, both descend from a common primitive Simian ancestor. From this among the living species, the Hylobatidae, though greatly differentiated by their long arms and sabre-shaped canines, depart least, several fossil Simiidae still less.

Also through his **mandible and teeth** Pithecanthropus deviated less from this common stock type than the three living Gigantanthropoidea and the Hylobatidae.

Besides the calvarium and the left femur, three different teeth were dug up at Trinil, and nearly a year before the discovery there of the first fossil remain of Pithecanthropus (the hindmost right upper molaris), a **mandibular fragment,** a small piece on the right of the symphysis, was found in the same Kendeng-layers, but at 40 km. distance on the E.S.E. of Trinil, namely at Kedung

Brubus, among other fossil remains of the Kendeng-fauna. Its specific gravity is the same as that of the teeth and the other remains of Pithecanthropus. A brief description of the mandibular fragment appeared at Batavia in 1891, in the "Verslag van het Mijnwezen", and I mentioned it, in a few words, in the "Natuurkundig Tijdschrift voor Nederlandsch-Indië" of the same year. I then considered it a remain of a not exactly determinable human species, "of another and probably lower type" than those existing and the extinct European diluvial species. This particularly on the ground of a peculiarity in connection with the place of attachment of the digastric muscle.

The mandibular fragment is a scalene-triangular piece of the corpus mandibulae, with as basis 36 mm. (measured rectilinearly) of the lower border, immediately on the right of the symphysis. The apex is formed by the root of the anterior praemolar tooth, which root has been preserved for the greater part. It is there 30 mm. high. There further is preserved the back half of the flat alveolus of the caninus with its root point and part of the front plane of the alveolus of the posterior praemolar tooth, under which is situated the front edge of the foramen mentale, 12 mm. above the sharp lower border. In its full thickness the corpus mandibulae has only remained preserved at the septum of the alveoli of the caninus and the anterior praemolar tooth.

I now ascribe also this mandibular fragment to Pithecanthropus erectus, because what the teeth teach us is quite corroborated by the morphological characters of this small, but all the same very significant piece of the mandible. The three teeth of Trinil are the upper left second and right third molar tooth, and the lower left anterior premolar tooth. The root of the lower anterior premolar tooth, which has remained preserved in the mandible fragment, closely resembles the root of that tooth of Trinil, and the alveolus still present in front of it, with the root-point of the canine tooth, betrays comparatively small canini, a caninus of the maxilla in keeping with this short premolar crown of the mandible. In view of this it is highly probable that the mandible fragment of Kedung Brubus derives from (another individual of) Pithecanthropus erectus, an at any rate rare species of the Kendeng-fauna.

The jaw and the teeth appear to have been almost perfectly human in their front part, particularly in the shape of the symphysis and the lower anterior premolar tooth and the canini, all of which differ so characteristically from those of the Manlike Apes. Crown and root of the premolar tooth are mesio-distally narrow, and the root, which has a double formation, is only divided near the point. Also

the alveolus of the lower caninus is flattened in the said direction.

Very remarkable is at the mandible fragment the extensive, broad, and long area of attachment of the digastric muscle, which makes the under part of the bone angular over a great length (as far as past m^3). This attachment of the digastric muscle which, as in the gibbons, extends far backward, is incompatible with a function of the tongue as an organ of speech. The muscle may, indeed, have been particularly powerful (much stronger in proportion to the size of the body than in the gibbons), because it had to bear a comparatively greater weight, on account of the erect attitude of Pithecanthropus.

Very different from that of the Manlike Apes, the symphysis must have been quite human. In the large Anthropoid Apes a plane applied at right angles to the alveolar line, between the caninus and the anterior premolar, always cuts the corpus mandibulae at a considerable distance before the back edge of the symphysis; in the small gibbon species it just strikes the back edge. In the mandibles of Mauer, Spy, and La Naulette, as well as in modern Man, on the contrary, this plane remains about 1 cm. behind the symphysis. The plane in question generally passes right through the septum of the alveoli of the teeth mentioned, and also in our fossil mandibular fragment this plane remained far (7 mm. according to estimation) behind the symphysis.

The root of the **anterior premolar** tooth in this fossil is broad, bucco-lingually 8.4 mm., and flattened in mesio-distal direction to 5.0 mm. Hence it has about the same dimensions as the root of the homonymous tooth of Trinil : 8.1 and 4.2 mm. Like this, it is composed of two root elements placed almost transversally, to be recognized by the two canals. The two teeth were evidently of the same type.

This tooth of Trinil was very human, as also appears from the diameters of the crown: 8.2 mm. bucco-lingual, 7.0 mm. mesio-distal, breadth index 117. It is undoubtedly an *anterior* premolar tooth, for the buccal cusp is much larger than the lingual one, hardly deserving the name of cusp, which feature makes the masticatory surface oblique, the buccal surface is strongly bent inward, bulging outward and much higher than the lingual surface; besides the middle crista is of a type only met with at anterior praemolar teeth of Anthropoids. In front and at the back the crown presents a facet of contact, with the canine tooth and the posterior premolar tooth of the lower jaw, and at the upper edge of the buccal surface a facet of wear with the caninus of the upper jaw. The

flat root of this tooth consists of a front-outer and a back-inner element. At the back-side they are separated only at the point of the former (the other point is broken off), over a length of 3.6 mm., but at the front side the disjunction of the root extends, as a deep fissure, 8 mm. more towards the crown. The total length of the front-outer root-element is 20.1 mm. The two roots of the homonymous tooth of the Anthropoid Apes, which are entirely or for the greater part separated and placed almost perfectly behind each other, are found here, as it were, from front backwards pressed almost crosswise and grown together.

The two **upper molar teeth** of Trinil, both with a triple disposition of the buccal roots, which have, however, been fused, evidently derive from one and the same individual. The rugosity of the crown of m^3 is much greater than in the Orang-utan, though in the shape of its crown this tooth presents a striking resemblance with some orang-utan teeth which I collected in caves in Central Sumatra. Besides a shape of crown as of m^3 is frequently met with in the Orang-utan. The slight development in both crowns of the hindmost buccal cusp, and the strong divergence of the roots may be in connection with the trigonocephalism of the cranium, which promoted the growth of the teeth in transversal direction above that in sagittal direction. The brachycephalism of the Orang-utan and the trigonocephalism of this individual Pithecanthropus have here the same result. For the rest, the circumstance that the three teeth were found at Trinil in exactly the same plane of the andesite tufa, with and comparatively near other remains of Pithecanthropus, renders the probability that they originate from one individual almost a certainty.

The crowns of the molar teeth have these measures, (mm.):

	bucco-lingual	mesio-distal	breadth index
m^3	13.8	12.0	115.0
m^2	15.3	11.3	135.4

As to size, m^3 is greatly exceeded by some orang-utan teeth from caves of Central Sumatra. Two of these attain bucco-lingually 18.7 and 20.2 mm. and mesio-distally 14.0 and 15.5 mm.; an m^3 thus reaches 19.0 and 17.7 mm.

The length of the two roots of the two molar teeth is as follows: the buccal of m^3 13 mm. and of m^2 14 mm., the lingual of m^3 12 mm. and of m^2 12.5 mm. They diverge greatly (the lingual deviates most from the vertical); between the outside of the points the distance is 16.5 mm. in m^3 and 18.0 mm. in m^2. The lingual roots are simple, the buccal ones on the other hand are composed, as stated above, in both teeth, of *three* fused elements: two outer

(buccal) root elements, and one at the inside of the foremost of the latter. In Man as well as in the Anthropoid Apes there are found as a rule one lingual and two buccal roots. The fusion of the two buccal roots points again to the mesio-distal shortening of the dentition, the incipient splitting up of the mesio-buccal root to the broadening in lingual-buccal direction. These are certainly individual characters, which establish that the two molar teeth belong individually together. The peculiar individual growth of the two teeth is, as was already said above, evidently in connection with the trigonocephalism, which caused the cranium to widen towards the bottom in its front half. The direction of the roots backwards may, possibly, have the same meaning, for the dental root grows towards the point, and there was more room towards the back.

The approach of the mandible and the teeth, as also of the femur, to the human type, and the large cranial capacity, added to considerations on the brain-quantities in nearly allied mammalian genera, all this leads me to the conclusion that Pithecanthropus should be considered as a member, but a distinct genus, of the family of the Hominidae.