GIANT EARLY MAN FROM JAVA AND SOUTH CHINA

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PREFACE

SCIENCE IS INDEBTED for the collection and knowledge of the material which is the subject matter of this paper to the initiative, energy, and passionately inquiring mind of Dr. G. H. R. von Koenigswald. The skull (*Pithecanthropus* Skull IV), the fragment of a lower jaw (Sangiran Mandible of 1939), and the fragment of a second lower jaw (Sangiran Mandible of 1941) came from the Trinil bed in the Sangiran District in central Java, where the bones were gathered by collectors trained by Dr. von Koenigswald. The three isolated teeth (*Gigantopithecus*) were acquired by Dr. von Koenigswald in 1934–1939, in Hong Kong in Chinese chemists' shops which he scoured in search of fossils whenever he passed through that city.

The war and its consequences prevented Dr. von Koenigswald from announcing the new discoveries. From 1937 to 1941, when I was in Peking and he was in Java, I was in close contact with him. Some of his material, in particular *Pithecanthropus* Skull IV, was prepared, photographed, drawn, and cast in the Cenozoic Research Laboratory in Peking, and in the last few years before its activities were halted the Laboratory was authorized to give financial support to his work in Java also. I was informed of each new discovery as soon as it was recognized, and could give my advice. But political conditions interrupted this cooperation, so beneficial to both parties. The last direct news I had from Dr. von Koenigswald was the announcement of the discovery of the Mandible of 1941. Several months later, through the courtesy of Ir. W. C. B. Koolhoven, Director of the Geological Survey of the Netherlands Indies, I received a cast of the jaw. But before the accompanying letter arrived in New York, all communication with Java ceased.

I found myself in a difficult position. I was busy preparing my study on the *Sinanthropus* skull, but this could not be completed without reference to *Pithecanthropus*, and Dr. von Koenigswald's publications on the latest discoveries did not appear. At the same time, all the essential data were at my disposal, casts, photographs, drawings, and measurements, and I had Dr. von Koenigswald's permission to use them. Under these circumstances I decided to publish all that I deemed necessary to the understanding of the morphology of the *Sinanthropus* skull and its position in the scale of human evolution. However, I could not restrict myself to the specimens of *Pithecanthropus* found earlier and ignore the rest, the less so, since the latest finds were of fundamental importance. The Mandible of 1941 is the most primitive hominid jaw ever recovered, and its gigantic proportions, exceeding in size and massiveness all that is known or could ever be expected of a hominid, bring an entirely new note into the picture. In addition, my study led me to conclude that *Gigantopithecus* is not a giant anthropoid, as Dr. von Koenigswald suggested, but a true hominid, more gigantic and more primitive than the Java mandible.

All this made immediate publication imperative, despite the fact that I had nothing at hand but the casts. Furthermore, I considered it necessary to prepare the way for a more thorough and systematic exploration of the localities which yielded these priceless finds, when conditions are more favorable. Since Java is cut off from communication and neither Dr. von Koenigswald nor the Geological Survey of the Netherlands Indies can be reached, I asked the Board for the Netherlands Indies, Surinam, and Curaçao, representing the government of the Netherlands Indies, for official permission to publish the material, being certain of Dr. von Koenigswald's personal consent. Mr. G. H. C. Hart, the Chairman of the Board, kindly approved the publication.

FRANZ WEIDENREICH
The American Museum of Natural History
July, 1944

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INTRODUCTION

IN A PREVIOUS PAPER[1] dealing with the influence of domestication and culture on the form and size of the skull and body of man, I considered particularly the general construction and shape of the skull and the manner in which its final form developed from foetal conditions and proportions. My conclusions can be summarized in the two following sentences:

The human skull can be interpreted as the dwarf form of an anthropoid type. . . . For reasons which can not be discussed here I conceive of the hominids as having derived from a small-sized primate, the large-sized form of which is represented, to some degree by the anthropoids of today.

In a more recent publication[2] in which the main reasons for this conclusion were subjected to detailed scrutiny, I was able to demonstrate that the special form and size of the human brain case and the reduction of jaws and teeth so characteristic of man are derived from an anthropoid form with a smaller brain case but with large, prominent jaws, conforming to the general correlation between these two constituents of the skull. The form of the human skull corresponds to that of certain dwarf animals where the brain is large in relation to the size of the body and, therefore, occupies a much greater space in the small skull than that of a relatively small brain in larger forms of the same zoological class. However, in man there is one essential difference. When compared with modern anthropoids man cannot be considered as a dwarf. Yet, since the configuration of the brain case and the correlated reduction of the jaws result from an enlargement of the brain (disregarding the particular factors involved in this increase), this growth, completely independent of any body size during the phylogenetic evolution, has the same effect on the definite form of the skull as has the relatively large brain on the small skulls of dwarfs. When I wrote the first paper I did not consider the possibility that man might not, by analogy, but in reality, be a dwarf form derived from giant anthropoid-like ancestors. There was no evidence to justify such an assumption. I rather thought of a relation such as exists today between a *Cebus* and a *Mycetes* where, in brain size, skull form, and body size, the former represents the dwarf type and the latter the large form. I did not think that the first hominids could be classified as pygmies and modern pygmies considered as the survivors of those early dwarfs, as J. Kollmann, the German anatomist and anthropologist, suggested in 1905.

Kollmann's theory is of special interest not so much for its purport, but because of the nature of the argument on which it was based. Kollmann premised as a general rule that in phylogenetic evolution all forms start as dwarfs and increase in size as they become more specialized. From this basic general idea he concluded that the first hominids must have been pygmies. At that time there were no paleontological facts which could be presented either as evidence or as suggestions of such development. On the contrary, the most primitive hominid-like forms which could be regarded at this time as possible ancestors of man were Dubois' *Pithecanthropus* (Trinil skull) and the Neanderthalians of Düsseldorf, Spy, and Krapina, all of them certainly not dwarfs. In my paper on the *Sinanthropus* skull[3] and in previous publications[4] I pointed out the meagerness of the proofs produced in the endeavor to minimize the paleontological data on the descent of man. Kollmann's case is typical. Dubois,[5] who believed that the Trinil femur and Trinil skull cap belonged not only to the same type but to the same individual, computed the stature of *Pithecanthropus* on the basis of the femur length (45.5 cm.) as 170 cm. or 5 feet 5¾ inches. Kollmann says:

I believe that the Trinil ape had exhausted all its faculty of development after having reached a stature of 170 cm. Another starting-form more flexible and more yielding to external influence than *Pithecanthropus* is necessitated to explain mankind's ripening.[6]

Thus the only paleontological evidence of early man then available was dismissed because it did not fit into Kollmann's arbitrary and fanci-

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[1] Weidenreich, 1925.
[2] Weidenreich, 1941b.

[3] Weidenreich, 1943b.
[4] Especially 1943a.
[5] Dubois, 1924.
[6] Kollmann, 1905. (Quotation translated from the original. F.W.)

ful picture of human evolution. However, to substantiate his speculations, Kollmann resorted to an argument which was first advanced by J. Ranke:

Ontogeny proves that early mankind had not flat but high skulls . . . for . . . the resemblance of infantile apes to infantile man is far greater than that of adult apes to adult man.[1]

Since the foetus of both apes and infantile anthropoids is characterized by high skulls, it must be assumed—in accordance with the experiences of breeders—that infantile apes, born with the prospect of advance, came into the world with well-shaped skulls and much brains and that their offspring never could relapse into the crude skull form of mother and father. On the contrary, it must further develop the favorable qualities it possessed as a child. . . . If this is true then races with flat vertex and protruding supraorbital ridges never could develop as the first human types from anthropoids but only those races which had high and well-shaped skulls as have the foetus of apes and the pygmies and the taller races of modern mankind.[2]

G. Schwalbe[3] answered Kollmann exhaustively and definitely. He demonstrated that the biological rule according to which highly organized forms must always derive from small forms does not hold true for species and genera, but only for orders as a whole—and the latter are not without exception. Furthermore, the greater prominence of the forehead in both the foetal and infantile stages is typical not only of the higher primates but of all mammals, and so must be considered the result of the greater growth rate of the brain as compared with the other organs during the entire ontogenetic development. Moreover, Schwalbe proved that the skull of living pygmies is no closer to the supposed large-brained archetype of man than any other skull of large races of modern mankind.

Despite Schwalbe's refutation, Kollmann's idea found new partisans from time to time. Klaatsch[4] alluded to it very superficially as he often did in his more popular works on the evo-

lution of mankind, but Hill-Tout[5] represented this principle as important and as a completely new approach to the problem of human phylogeny. In a rejoinder to these authors, W. K. Gregory[6] rightly stressed the point that as a consequence of these ideas the study of ontogenetic evolution of living creatures would render entirely superfluous the study of the paleontological forms of the original types from which they derived; the course of human evolution could be reconstructed from certain ontogenetic stages. If, for example, the kind of primary relation between anthropoids and hominids could be deduced only from the relatively predominant size of the brain and brain case shown by infantile anthropoids, the Pekinese must be considered the prototype of the dog, for its skull has preserved most accurately the juvenile ontogenetic stage, while it had been lost in large canine forms like the Irish wolf hound and others. However, the paleontological data prove just the opposite, namely, that early dogs possess more or less wolf-like skulls.

The theory according to which ontogeny is a slavish repetition of phylogeny, not only in its general trend but also in minor details, found its most ardent advocate in the Dutch anatomist and anthropologist, L. Bolk. He was so convinced of the infallibility of that rule that he neglected all paleontological evidence when he made special features, for instance, the development of the human chin,[7] the subject of a comparative study. The bare paleontological facts supplied by the new discoveries of *Sinanthropus* and *Pithecanthropus* have cut the ground from under all such speculations. It can now be considered as certain that man's ancestors resemble modern man no more than do modern anthropoids, in spite of Kollmann's and Bolk's suggestions. The latest finds in Java also prove that pygmian types cannot be considered as immediate progenitors of modern man. On the contrary, the newest discoveries reveal that the most primitive hominids now known were gigantic forms which surpassed all anthropoids and hominids, living and fossil, in size and robustness of mandibles and teeth.

[1] Ranke, 1897. (Quotation translated from the original. F.W.)
[2] Kollmann, 1905. (Quotation translated from the original. F.W.)
[3] Schwalbe, 1906.
[4] Klaatsch, 1920.

[5] Hill-Tout, 1921.
[6] Gregory, 1925.
[7] Bolk, 1926b.

I. THE NEW FINDS IN JAVA
A. VON KOENIGSWALD'S EARLIER DISCOVERIES

It is one of the greatest ironies in the history of paleoanthropology that the most surprising and revolutionary discoveries which shed real light on the origin of man should come from the periphery of the Old World. These are the very regions which, according to the theory of the old anthropological school, were the least fitted to provide evidence on this most discussed problem. In the eyes of many students of early man there was only one cradle of mankind located somewhere near the center of the habitable earth, where all the decisive steps of human evolution must have been taken, once evolution was set in motion. The periphery of the earth sheltered only obsolete forms—so runs this doctrine—which were forced to these areas by pressure from the new types constantly produced at the center, and as a result were doomed to final extinction.

But the facts give no support to such a theory. On the contrary, no region of the earth has yielded so many successive evolutionary stages of hominids: the *Pithecanthropus* types, *Homo soloensis*, and Wadjak man (proto-Australian), as the small outpost of Java.[1] In contrast, the supposed center of human evolution, the European continent and western Asia, seems to be sterile, although their soil has certainly been plowed over much longer and more thoroughly by fossil hunters.

A new phase in the history of paleoanthropology was inaugurated in 1931, after a lull of more than 40 years, when von Koenigswald described a *Pithecanthropus* mandible from the Trinil beds of Sangiran, thereby opening a new site of fossil human deposits in Java. So far, this mandible is known only from the preliminary note[2] in which von Koenigswald announced its discovery. Since then it has been completely separated from the adhering matrix in the Cenozoic Research Laboratory of Peking. The new photographs, also taken there, have been published by von Koenigswald[3] as an illustrated appendix to a paper in which the author does not deal with the mandible itself but discusses only the supposed relationship between *Pithecanthropus* and the South African

man-apes. In attributing the jaw to *Pithecanthropus*, as "Mandible B," von Koenigswald has been influenced by the consideration that a hominid mandible recovered from geological strata identical with those of Trinil must necessarily belong to the same type as the Trinil skull which Dubois called *Pithecanthropus*.[4]

However, the first human specimen found by Dubois in Java was also a fragment of a mandible which he[5] later attributed to *Pithecanthropus*, although it was not recovered from Trinil itself, but from a similar deposit (Kendeng) at Kedung Brubus. This fragment, designated in the aforementioned list of the *Pithecanthropus* material as "Mandible A," is smaller, especially in height, than the Sangiran mandible. It also differs greatly in the development of the digastric fossa. Shortly after the discovery of the Sangiran mandible, the same site yielded a calvaria, defective, it is true, but much more complete than that of Trinil, since the temporal bones of both sides are preserved. The resemblance of this skull to Dubois' holotype of *Pithecanthropus* is so great that von Koenigswald did not hesitate to attribute it to the same form.[6] In our list (see above) the skull is designated as "*Pithecanthropus* Skull II" while Dubois' holotype is listed as "Skull I."

The political situation has prevented von Koenigswald from publishing his study of this skull. But in the illustrated appendix to his latest publication, the various aspects of the skull are illustrated in photographs and drawings.[7] As this skull is, so far, the best preserved and most complete representative of *Pithecanthropus*, I used it as the standard for all the comparisons with *Sinanthropus* in my monograph on the *Sinanthropus* skull.[8] When I visited Java in the fall of 1938 Dr. von Koenigswald showed me a case full of bones which had just been collected from the Trinil beds of the Sangiran District. Among these were the frag-

[1] Weidenreich, 1943b.
[2] Von Koenigswald, 1937.
[3] Von Koenigswald, 1942.

[4] See the list of *Pithecanthropus* material in von Koenigswald and Weidenreich, 1939.
[5] Dubois, 1924.
[6] Von Koenigswald, 1938.
[7] Von Koenigswald, 1942, Pl. 1, Figs. 1–4; Pl. 2, Figs. 1–4; Pl. 3, Figs. 2–3; Pl. 4, Fig. 3; and pp. 213–215, Figs. 1–3.
[8] Weidenreich, 1943b, cf. Figs. 259, 260, 264 and Tables 19–21.

ments of a juvenile human calvaria consisting of the two united parietal bones with the matrix still adhering inside.[1] Its appearance left no doubt that the type to which this skull belonged was the same as that of Dubois' Trinil skull cap and the more complete calvaria found by von Koenigswald two years before at the same site. Some days later, when we searched the spot where this calvaria had been found, we found a small piece of the occipital squama which fitted perfectly into the break of the main fragment. We described this skull as *Pithecanthropus* Skull III in a joint preliminary paper.[2]

In January, 1939, Dr. von Koenigswald went to Peking to study the *Pithecanthropus* fragments with the facilities afforded by the Cenozoic Research Laboratory, and also to compare his material with that of *Sinanthropus*. He brought with him an upper jaw collected in the Sangiran District a few days before he left Java. It was coated with a thick matrix which was later removed in the laboratory. Since the bone fractures were fresh, it seemed reasonable to believe that other parts of the skull were still buried at the spot where the jaw was found. Accordingly, von Koenigswald directed his collector to search the site again. The search was successful. The greater part of the calvaria was found and immediately sent to Peking. The calvaria consisted of three larger and two smaller pieces, apparently broken quite recently, their outer and inner surfaces covered with the same thick matrix as that which coated the jaw. After preparation, it was obvious that both jaw and calvaria had been badly crushed, but as the broken and dislocated fragments were fixed in an unnatural position the crushing must have occurred before fossilization set in. Dr. von Koenigswald has shown photographs illustrating the unprepared and prepared maxilla and fragments of the calvaria in Figs. 1 and 2 in his previously mentioned paper.[3] I have used photographs and drawings of the prepared calvaria bones in my paper, "Man or Ape,"[4] in the paper on the torus occipitalis,[5] and finally in

the monograph on the *Sinanthropus* skull.[6] The prepared maxilla is also illustrated in my paper of 1940a[7] and in that last mentioned[8] as well as in our joint paper.[9] Although the skull of the new find is much larger than Dubois' *Pithecanthropus* holotype and the two skulls subsequently recovered, Skulls II and III, we did not hestitate to attribute both calvaria and maxilla to *Pithecanthropus*, designating them as Skull IV,[10] explaining the difference in size and heaviness as due to differences in sex. Furthermore, as the upper teeth have approximately the same pattern as the *Sinanthropus* teeth and as they are only slightly larger than the lower teeth of "Mandible B," the diagnosis seemed to be correct.

It had been agreed in Peking that Dr. von Koenigswald should describe Skull IV as soon as possible but that, in the meantime, I should be free to use all data, photographs, and drawings in so far as they were indispensable to my comparative studies on early man. I have, therefore, referred to the skull in all my subsequent publications. However, von Koenigswald's latest discoveries necessitate a revision of the opinion I first advanced, namely, that Skull IV was a male individual of *Pithecanthropus erectus*, the same type as represented by Skulls I and II. The whole question will be discussed later in a special section (p. 95). Yet, since the data published so far on Skull IV give an inadequate conception of the skull and its bearing on the manifold problems which stem from von Koenigswald's latest discovery, I have decided to include it. in this study. The description suffers greatly, however, from the poor condition of the skull. This was indeed so bad that the reconstruction, particularly in the matter of the missing parts, may not be quite accurate. Inaccuracy in the reconstruction also applies, but to a lesser degree, to the parts that were preserved. A more correct picture will be achieved when it will be possible to restore the dislocated fragments on the original and not on the cast as I was forced to do.

[6] Weidenreich, 1943b, Figs. 229, 230, 244, 270, 272.
[7] Weidenreich, 1940a, 32.
[8] Weidenreich, 1943b, Fig. 248.
[9] Von Koenigswald and Weidenreich, 1939, 927.
[10] In his paper on Pleistocene geology and early man in Java, H. de Terra (1943b) credits me with the recognition of *Pithecanthropus* Skull IV, apparently confusing Skull IV with Skull III. The history of these discoveries as reported by de Terra must be corrected on this point.

[1] Von Koenigswald, 1942, cf. Pl. 7, Fig. 1; and Weidenreich, 1943b, Figs. 247, 261.
[2] Von Koenigswald and Weidenreich, 1938.
[3] Von Koenigswald, 1942.
[4] Weidenreich, 1940a, 32, 33.
[5] Weidenreich, 1940b, Pl. 6, Figs. 23–25.

B. VON KOENIGSWALD'S LATEST DISCOVERIES

In the spring of 1939, when von Koenigswald returned from Peking to Java he found waiting for him a fragment of a mandible which had been collected at Sangiran during his absence. In a letter to my New York address, von Koenigswald informed me of this discovery and described its most characteristic features. Since I was skeptical, I asked him for photographs or, if possible, a cast. When I received the cast in 1940, I identified the fragment, not as a portion of a hominid mandible but as one from an anthropoid, possibly an orang-utan, isolated teeth of which very commonly occur in the Trinil horizon. Von Koenigswald did not accept my view. In a letter dated February 3, 1941, he wrote me: "It certainly does not belong to *Pithecanthropus* (symphysis) nor to *Simia* (dental arch). Perhaps it is a kind of ancestral pithecus."[1] In a later letter (May 7, 1941) he informed me that after having compared the mandible under discussion with a rather large number of orang-utan mandibles, he maintained his opinion that it certainly had no relation to either orang-utan or *Pithecanthropus*. In the meantime, von Koenigswald apparently has been corroborated by the discovery of a second mandible "which," as he wrote, "has been found [end of April, 1941] by our collector about a week ago."[2] Considering the significance of the discovery of this second mandible fragment, I feel justified in quoting literally von Koenigswald's first description of the new find. It reads as follows:

It is a most surprising find: a part of a right mandible with P₃ to M₁—large teeth (first premolar not essentially different from *Sinanthropus*, especially from No. 85 of your collection, either in shape or size —length ca. 10 mm.—), but it is a disproportionate, beast-like mandible. It is so large that *Pithecanthropus, Paranthropus*, Peking Man and Heidelberg Man are elegant and dwarfish in comparison with it. . . . It is 44 mm. high and about 27 mm. thick. . . . The symphysis is more than 25 mm. thick; there is no "simian shelf"; the alveolus of the canine is small.[3]

To give me an idea of the size of the fragment von Koenigswald drew the contours on the sheet as they appear in lateral aspect. As to the mandible fragment found first he now remarks that it "seems to belong to a small female individual of the same type as the big one."[4] Von Koenigswald adds:

The new, giant primate is clearly related to the hominid group. But I believe, on the other hand, that there are also relations to the Siwalik anthropoids. It is now the problem of the Pliocene man which we have to solve. What a pity that it cannot be solved on Java's soil because of the marine character of most of the Pliocene layers and the great scarcity of most of the remains of fossil mammals in Java.[5]

Finally, von Koenigswald announced in his letter that he was preparing a short description. I was later informed by Dr. John C. Merriam, formerly President of the Carnegie Institution of Washington, that he had received a letter from von Koenigswald, together with two manuscripts for publication. Both papers[6] deal with the relation of *Pithecanthropus* to the South African Anthropithecinae but do not mention the newly discovered mandibles.

After having received von Koenigswald's letter announcing the discovery of the second mandible, I asked him for a more detailed characterization, substantiated by photographs or, if possible, casts. I never received a reply, but, in December, 1941, a parcel arrived from Bandoeng, addressed to the Department of Paleontology of the Amerian Museum of Natural History, Drs. W. K. Gregory and W. Granger. This had been sent by Ir. W. C. B. Koolhoven, Director of the Geological Survey of the Netherlands Indies. The parcel contained a cast of Dubois' mandible from Kedung Brubus, a cast of the mandible fragment discovered in 1939, and two casts of the giant mandible of 1941. One of the latter was intended for me as was shown in a letter dated January 15, 1942,

[1] Von Koenigswald, personal correspondence, February, 3, 1941.
[2] Von Koenigswald, personal correspondence, May 7, 1941.
[3] Von Koenigswald, personal correspondence, May 7, 1941.

[4] Von Koenigswald, personal correspondence, May 7, 1941.
[5] Von Koenigswald, personal correspondence, May 7, 1941.
[6] One published in the meantime in the Yearbook of the Carnegie Institution for 1941 and the other as Publication 530 of that institution.

which arrived later. The letter contained a list of the casts in the parcel, in which the two new mandibles were entered under the name *Meganthropus palaeojavanicus* von Koenigswald. They were described as follows:

1, Fragment of lower jaw with two molars from the lower Pleistocene of Sangiran near Solo, Central Java, 1939. Probably female specimen. *Meganthropus* is a newly discovered fossil hominid perhaps related to *Australopithecus*. 2, Fragment of an extremely heavy lower jaw with the first molar and both premolars, Sangiran, 1941, male specimen.

From Koolhoven's letter it follows that von Koenigswald considered that the two mandibles discovered in 1939 and 1941 belonged to the same type; the smaller (1939), a female, and the giant (1941), a male. Furthermore, von Koenigswald regards this type neither as an anthropoid (orang-utan) nor as a *Pithecanthropus* form but, as his letter of May, 1941, shows, as related to the pre-hominids (*Pithecanthropus* and *Sinanthropus*) as well as to the Siwalik anthropoids and the Australopithecinae. Immediately upon the arrival of the casts I tried to communicate with Dr. von Koenigswald in order to obtain more details and, in particular, to secure his consent to an announcement of the discovery in consideration of its extraordinary significance. A cable sent for this purpose remained unanswered. A second attempt to communicate with him through the Director of the Geological Survey of ·the Netherlands Indies, Ir. W. C. B. Koolhoven, and the Trade Commissioner for the Netherlands Indies in New York produced the reply that an air-mail letter was on the way. This letter never arrived. Also an air-mail letter which I wrote to Dr. Koolhoven on this subject was returned with the stamp "service suspended"; Java had, in the meantime, been occupied by the Japanese.

For the present, therefore, we must rely on: 1, the data already at hand relating to the site from which the new specimens came and to von Koenigswald's own classification and nomenclature; and 2, the casts made from the originals and sent to me and to the American Museum of Natural History, respectively. In spite of the uncertain and limited character of the evidence furnished by the casts, I think it is sufficient to give the scientific world knowledge of these new discoveries and of the conclusions I have

drawn from the facts they reveal. When, once again, normal conditions are restored and the specimens themselves become available for scientific examination, my report must necessarily be completed by adding photographs from the originals, and, above all, by correcting details and measurements.

The story of new discoveries did not end with the recovery of these two mandible fragments. In 1935, Dr. von Koenigswald published a paper which dealt with fossil material he had purchased in Chinese apothecary shops in the Far East. Among the teeth purchased in Hong Kong which came, apparently, from fissures and caves of "probably pleistocene age"[1] located in South China were those of a large orang-utan. In addition to these orang-utan teeth there was also "an enormous, fairly worn, right, lower third molar which cannot be attributed to *Simia*." Von Koenigswald says, "As I am unable to ascribe the tooth to any one of the known primates I call it *Gigantopithecus blacki*, n. g., n. sp."[2] Later, also in Hong Kong, he acquired a second tooth of the same type, an upper molar, and in 1939, while on his return to Java from Peking, he secured a third tooth (again in Hong Kong). This last one, curiously enough, was another lower third molar; but this time the specimen was a left molar, slightly worn. While in the two molars acquired earlier the roots are broken off or, properly speaking, gnawed off by rodents, in the third specimen only the anterior root is missing, while the posterior one is completely preserved.

In none of his subsequent publications does von Koenigswald revert to these teeth. Even in his latest paper in which he compares the teeth of pre-hominids and hominids with those of Australopithecinae these finds are neither noted nor discussed. This is the more surprising because, in the meantime, Broom[3] put *Gigantopithecus* "somewhere near" the origin of man and near the *Australopithecus* group of anthropoids. The inclusion of the *Gigantopithecus* teeth in this list of von Koenigswald's newest discoveries of hominid forms proves that I not only agree with Broom, but dare to be still more definite in the identification. This will be clearly shown later.

[1] Von Koenigswald, 1935.
[2] Von Koenigswald, 1935.
[3] Broom, 1939b.

II. *PITHECANTHROPUS* SKULL IV (*PITHECANTHROPUS ROBUSTUS* WEIDENREICH)

THE HISTORY OF THE DISCOVERY of this skull has been related above. Unfortunately, only the posterior half of the brain case and the lower portion of the maxilla have been preserved. The remaining portion of the calvaria consists of almost the entire occipital bone, including the greater part of the occipital foramen with the condyles, the two temporal bones (except for the medial portion of the pyramid and the zygomatic process on either side), and approximately the posterior three quarters of the two parietal bones. The portion of the maxilla that is preserved consists of the entire alveolar process (except for the posterior part of the left side). Almost the entire palate, the floors of the nasal cavity, the maxillary sinuses on either side, and the lower part of the anterior nasal aperture also remain. In addition, the teeth are *in situ*, except for the four incisors and the left M^2 and M^3. An isolated incisor, which I consider to be the right lateral one, was also discovered with the maxilla.

After preparation and the adjustment of those pieces which appeared to have been freshly broken (Fig. 1a, b, d; Pl. 1b; Pl. 3a), it was obvious that the brain case had been crushed, apparently with great force. Cracks spread over the entire calotte, there are deep impressions where the occipital and temporal bones have been telescoped into each other (Fig. 1a, e; Pl. 2a; Pl. 3a), and most of the fragments have been dislocated. A wide cleft also passes through both cap and base in an oblique direction from the right at the front to the left at the rear (Fig. 1b, c, d, e; Pl. 1a, b; Pl. 2a, b; Pl. 3a). Apparently these injuries occurred not only before fossilization, but before the flesh had decomposed; otherwise mineralization could not have fixed the bones and bone fragments in such unnatural positions. An excellent example of this dislocation and subsequent fixation in the wrong place by fossilization may be observed on the fragment designated as bp. It is probably the basilar process of the occipital bone which was broken from its normal position by the blow cleaving the skull and has been turned to the left side of the outer surface of the base where it is still attached. The maxilla displays the same signs of violence. Several cracks extending over the palate have produced some

dislocations; in particular, the left side of the alveolar process has been affected and moved inward (Fig. 2c and d; Pl. 3d).

These breakages and dislocations conceal the structural peculiarities of the skull only to a moderate degree but, combined with the complete loss of the frontal region and the upper portion of the face, they make it very difficult to determine its original size and form, and further, to express these in exact figures. Yet the fragments themselves are so well preserved that it will be relatively easy to restore the dislocated sections to their natural positions. It was impossible to do this immediately after preparation, but it should be done as soon as the skull is again accessible. In the meantime, I have attempted to reconstruct the skull, using the cast instead of the original. The work was done in the Paleontological Laboratory of the American Museum of Natural History by Mr. Otto Falkenbach to whose understanding and technical skill the achievement must be credited. In addition to readjusting the fragments, the missing parts of the calvaria and face had to be modeled. As both base and vertex of the calvaria are preserved in their natural positions, unaffected by the crushing (Fig. 1d and Pl. 1b), the height of the frontal portion of the brain case is given. The pterygoid process which has been preserved (p. 26, Fig. 1e, Pl. 1b) dictates the level of the orbital floor, on the one hand, and that of the palate on the other, although the second is not so certain as the first. On the right side, the lateral wall of the brain case is broken off just in front of the crista infratemporalis (ci, Fig. 1e), so that the floor of the fossa temporalis up to the sutura sphenofrontalis (ssf) is preserved. This, together with the posterior end of the right alveolar process which is also preserved, offers a clue to the total length of the calvaria. When the two dislocated temporal bones were readjusted, the biauricular breadth could be measured. For the reconstruction of the mandible, *Pithecanthropus* Mandible B was taken as a model and the missing parts supplied from *Sinanthropus* Mandible G I. This reconstruction is shown in Pls. 4 and 5. When it is possible to make a restoration on the original specimen, some corrections may be necessary, particularly in the frontal region of the brain
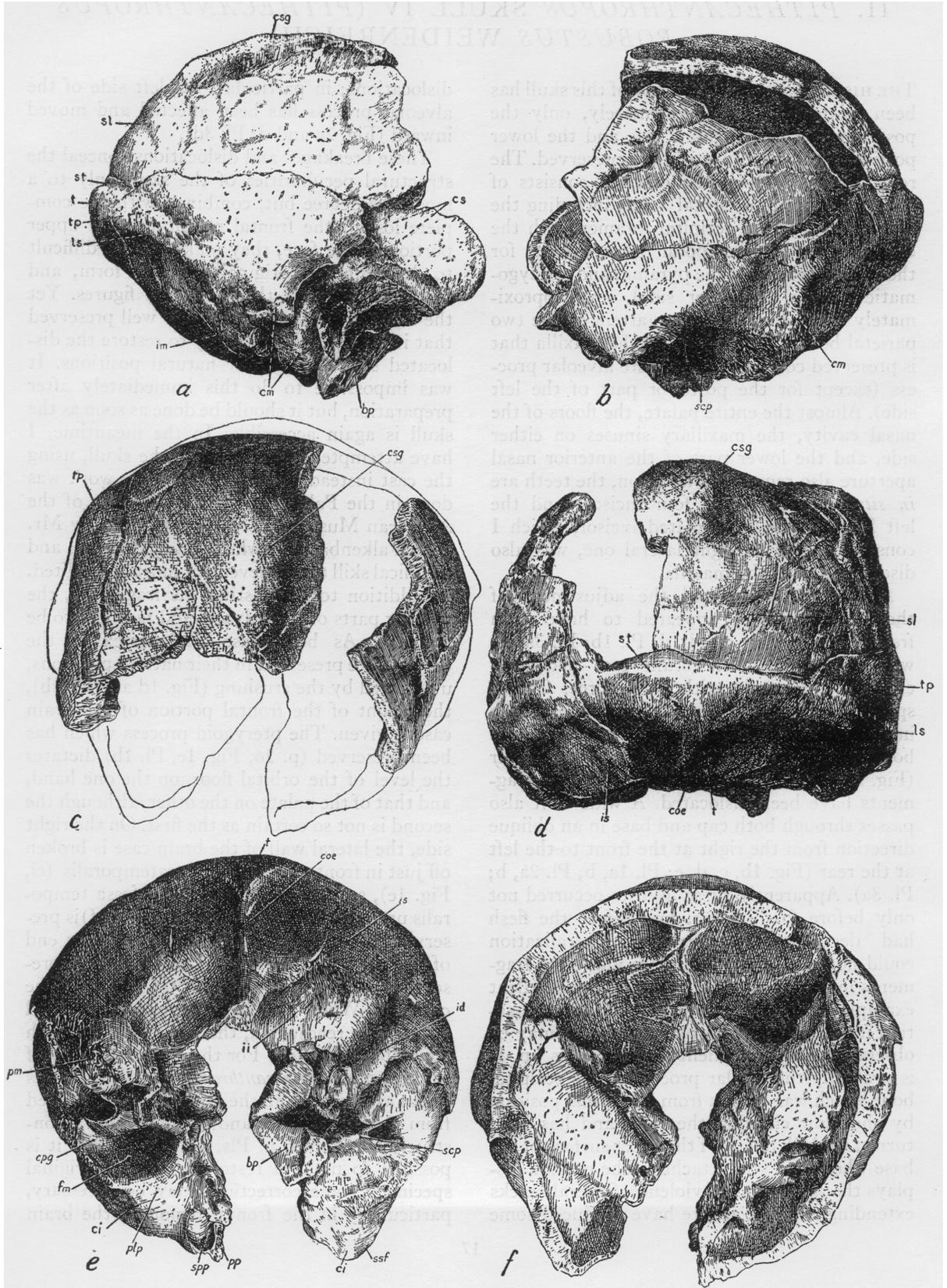
FIG. 1. *Pithecanthropus robustus* (*Pithecanthropus* Skull IV).
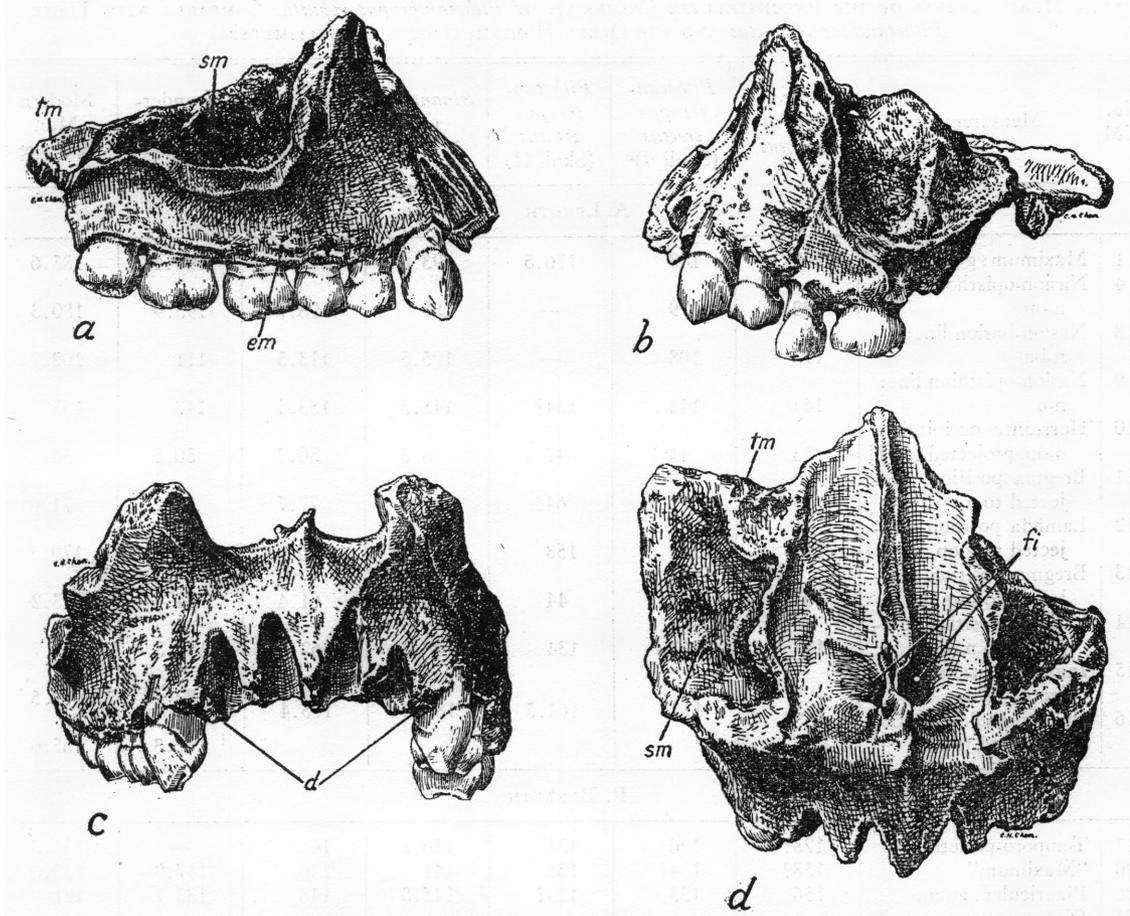
FIG. 2. *Pithecanthropus robustus* (*Pithecanthropus* Skull IV) maxilla.
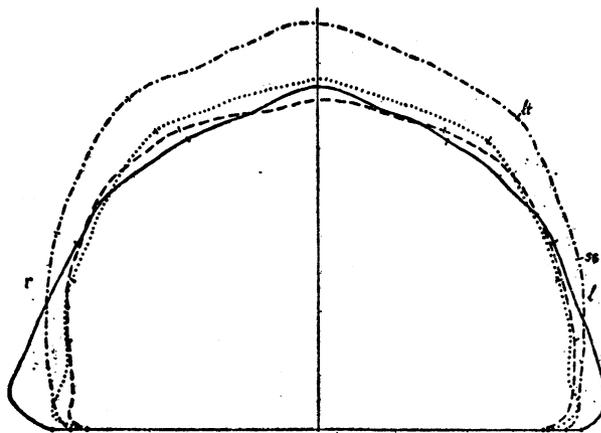
FIG. 3. Interporial coronal craniograms superimposed on the po-po axis.

TABLE 1

LINEAR MEASUREMENTS OF THE RECONSTRUCTED CALVARIUM OF *Pithecanthropus robustus* COMPARED WITH THOSE OF *Pithecanthropus erectus* AND THE OTHER HOMINID GROUPS (IN MILLIMETERS)

No. CM	Measurement	Pithecan- thropus robustus	Pithecan- thropus erectus (Skull I)[a]	Pithecan- thropus erectus (Skull II)	Sinanthro- pus Average	Homo soloensis Average	Neander- thalians Average	Modern Man Average
	A. LENGTH							
1	Maximum: g-op	199	183	176.5	193.6	209	198.4	185.6
4	Nasion-opisthocranion: n-op	192.5	179	—	189	198.7	193.9	180.3
8	Nasion-basion line: n-ba	113	108	—	105.5	113.5	111	102.7
9	Nasion-opisthion line: n-o	144	142	134?	145.3	153.4	148	135
10	Horizontal occipital: o-op, projected to FH	53	41	42	48.3	50.7	50.5	56
11	Bregma position, pro- jected to g-op	85	77.5	64?	77.3	77.7	73.2	71.6
12	Lambda position, pro- jected to g-op	172	162	153	172	176.6	180.5	179.5
13	Bregma position, pro- jected to n-o	64	55	44	56.7	61.4	44.4	33.2
14	Lambda position, pro- jected to n-o	152	143	134	148.2	162	155.3	148.7
15	Inion position, pro- jected to n-o	185	172	164.5	180.3	195.4	182	169.5
16	Opisthocranion position, projected to n-o						182.3	165.6
	B. BREADTH							
17	Temporo-parietal	125?	126	131	136.2	146	—	131.5
20	"Maximum"	158?	134?	135	141	146	147.9	133.6
26	Biauricular: au-au	156	135	129?	145.5	148	133.7	121
33	Distance between tem- poral lines	78?	—	67	93.5	112.8	—	98.6
	C. HEIGHT							
34	Basi-bregmatic: ba-b	102	105	105?	115?	122.5	125	134
36	Auricular, above FH	90	92	89	98.4	107.4	111.5	113.5
40	Bregma (I), above g-op	49	61	60.5	72.9	76.7	73.5	82.7
41	Calvarial, above g-op	49	61	66	74.6	78.8	82.5	87.4
44	Bregma (II), above n-o	76	82	78	91.3	98.7	98.2	107.7
45	Vertex, above n-o	88	89	88	101.3	105.7	114.2	124.6
46	Lambda, above n-o	78	78	74.5	82.3	84.1	88.8	94.6
47	Opisthocranion, above n-o	52	45	37	47	36.3	54.8	67
48	Inion, above n-o						35.5	36.8
	D. ARCS AND CHORDS							
54	Frontal arc: n⌒b	116	111	107?	120.3	130.8	123.7	128
56	Frontal chord: n-b	99	100	90?	109.8	116.7	108.8	112.1
58	Parietal arc: b⌒l	89	91	94	102.5	107.4	122.8	130.4
59	Parietal chord: b-l	90	87.5	91	96.2	102	110.3	116.5
60	Occipital arc: l⌒o	117	103	101	114	116.8	116.6	114
61	Occipital chord: l-o	78	78	75	84	88.2	89.3	92.8
	E. CAPACITY							
74	Cranial capacity in cc.	c. 900	c. 900	775	1043	1100	1400	1300

[a] After Weinert, 1928.

TABLE 2

ANGLES OF THE RECONSTRUCTED CALVARIUM OF *Pithecanthropus robustus* COMPARED WITH THOSE OF *Pithecanthropus erectus*, THE OTHER HOMINID GROUPS, AND ANTHROPOIDS

No. CA	Measurement	Pithecan- thropus robustus	Pithecan- thropus erectus (Skull I)[a]	Pithecan- thropus erectus (Skull II)	Sinan- thropus Aver- age	Homo soloensis Aver- age	Neander- thalians Aver- age	Modern Man Aver- age	Anthro- poids Aver- age
2	Frontal inclination I: b-n∠n-op	35°	41°	46.5°	44.3°	48.7°	48°	50.8°	—
3	Inclination of frontal squama: b-g∠g-op	30°	38°	40°	42.5°	45.8°	45°	49.2°	up to 89.5°
8	Occipital inclination II: l-op∠op-g	52°	62°	62.5°	62.7°	62.8°	67°	75.9°	—
10	Occipital curvature: l-op∠op-o	91°	108°	103°	103.2°	98.2°	110.3°	122.6°	—
11	Frontal inclination II: b-n∠n-o	59°	57°	60°	58°	57.6°	66.3°	72.6°	52.5°
12	Inclination of whole occipital: l-o∠o-n	97°	91°	92°	93.1°	98°	96.5°	99°	83.1°
14	Cranial base: ba-n-o	8°	5°	—	6°	7°	6°	6°	10°
15	Inclination of occipital foramen: n-ba-o	149°	162°	—	155°	154.7°	159°	156°	127°

[a] Partly after Weinert, 1928.

TABLE 3

INDICES OF THE RECONSTRUCTED CALVARIUM OF *Pithecanthropus robustus* COMPARED WITH THOSE OF *Pithecanthropus erectus*, THE OTHER HOMINID GROUPS, AND ANTHROPOIDS

No. CI	Measurement	Pithecan- thropus robustus	Pithecan- thropus erectus (Skull I)[a]	Pithecan- thropus erectus (Skull II)	Sinanthro- pus Average	Homo soloen- sis Average	Neander- thalians Average	Modern Man Average	Anthro- poids Average
1	Length-breadth	79.3	73.2	76.5	72.2	72.0	73.3	72.8	84.3
3	Length-total height	51.2	57.4	59.6	59.4	60.2	63.2	72.9	74.3
4	Length-auricular height	45.2	50.2	52.2	50.9	53	56.7	61.7	—
6	Breadth-height	64.6	78.3	77.8	75.6	84.2	85.2	100.6	88.3
7	Breadth-auricular height	57.0	68.5	68.1	70.3	74.9	76.2	85.3	—
8	Bregma height I	24.6	33.3	34.2	37.6	37.8	36.7	45.2	—
9	Calvarial height to g-op line	24.6	33.3	35.3	38.5	39.5	40.9	47.5	27.9
11	Bregma height II	52.7	57.7	58.2	62.7	64.4	66.8	78.5	46.1
12	Vertex height	61.1	62.7	64.2	69.4	69	77.7	91	54
13	Lambda height	54.1	54.9	55.6	56.6	54.7	60.4	69.1	44.7
14	Opisthocranion height	36.1	31.7	27.6	32.3	24.1	37.6	49.6	22.2
15	Inion height						24.2	27.3	42
16	Bregma position, above n-o	44.3	42.3	32.9	38.9	40.2	29.8	24.2	35.3
17	Lambda position, above n-o	105.4	100.7	100	102	105.7	105.1	109.3	95.3
18	Occipital length I	26.6	22.5	24.1	25.7	25.5	25.8	30.6	12.7
19	Occipital length II, above n-o	−28.3	−22.1	−22.5	−24	−28.7	−23.3	−21.8	−6.4
26	Lower parietal breadth	80.2	94.3	101.5	94.5	97.8	92.5	107.9	85.1
27	Upper parietal breadth	49.9	—	51.8	64.2	76.9	66.4	81.2	—
34	Frontal curvature	85.4	90.1	—	89.9	89.5	88.8	85.7	87.4
39	Parietal curvature	96.8	96.1	95.9	94.1	95.7	93.2	89.4	95.3
40	Occipital curva- ture	66.6	75.7	75	73.8	75.7	77.7	80.8	89.4
43	Nasion-basion length	78.6	76.2	—	72.6	74.1	75	75.3	83.8

[a] Partly after Weinert, 1928.

case and the superior portion of the face. In any case, this restoration, imperfect though it may be, provides a sufficient basis for the comparison of Skull IV with the two other *Pithecanthropus* skulls and with the skull of *Sinanthropus*.

To secure a good basis for such comparison, it seems well to distinguish first between those features shown in the preserved portions of the skull and those features which become clearer by the reconstruction of the missing parts. The features belonging to the former category will be considered first. For measurements see also Tables 1–3.

A. MORPHOLOGICAL CHARACTER OF THE SKULL BASED ON THE NON-RESTORED PARTS

The skull is much larger than *Pithecanthropus* Skulls I and II. The greatest breadth (the intercristal breadth, which lies a little behind the biauricular breadth—a characteristic location in early hominids[1])—is 158 mm. against 135 mm. in Skull II (Table 1). The height measured from the basion to the vertex is, however, only 102 mm., while in Skull II the corresponding height is about 105 mm. This gives a breadth-height index of 64.6 against 77.8 in Skull II (Table 3). The greatest length of the portion of brain case that is preserved—from the mid-sagittal point of a transverse vertical plane laid through the sphenofrontal suture to the opisthocranion, which coincides with the inion —is 150 mm. In Skull II the same measurement is only 136 mm. On the other hand, the cap is surprisingly low, especially in the obelion and occipital regions, and the nuchal plane is very flat (Fig. 1a, b). This is not an artificial state caused by the crushing of the skull, for the entire mid-sagittal region from the vertex to the opisthion was not affected and bears no signs of fracture, depression, or dislocation, conditions confined to the parts lateral to the mid line. The lowness (for measurements of the reconstructed skull see later and Tables 1–3) is indicated by the brevity of the occipital chord (lambda-opisthion), the narrow occipital flexional angle, and the small occipital curvature index. The length of the chord is 78 mm.; that of the arc is 117 mm.; the index is 66.6; the angle measures 91°. In *Pithecanthropus* Skull II, which otherwise is much smaller, the chord is 75 mm.; the arc, 101 mm.; the index, 75; and the angle, 103°. None of the *Sinanthropus* skulls has such a low index and narrow angle. The only fossil hominid with an equally low index and angle is

Homo soloensis Skull X. Its occipital curvature index is 68.4, and the angle of the occipital curvature is 91°. The Rhodesian Skull, which has been considered as exceptional because of the flatness of its nuchal plane and the narrow angle of its occipital curvature, measures as follows: length of the occipital chord, 89 mm.; length of the occipital arc, 118 mm.; index, 74.1; angle, 99°.

In *Pithecanthropus* Skull IV the predominance of the basal breadth over the greatest parietal breadth is much more pronounced than in Skull II or any of the *Sinanthropus* skulls. Because of the poor condition of the parietal region on either side, it is difficult to express the breadth at the different altitudes by exact measurements (see below), but there is no doubt of the almost triangular form of the skull, as shown by the transverse vertical section through the porion (Fig. 3).

Some of the non-metrical characteristics of the brain case have already been described in previous papers.[2] Leaving details to these descriptions, I wish to stress here those points in which Skull IV differs from Skull II to such a degree that their separation appears justified. Above all there is the peculiar development of the sagittal crest (csg, Fig. 1a, b, c, d; Pl. 3a). This consists not only of a continuous keel-like elevation, accentuated by a parasagittal depression on either side (cf. also Fig. 3), but also of a chain of knob-like thickened areas which form the crest from the vertex close to the occipital torus. No similar structure has been found in *Pithecanthropus* Skulls I and II or in any of the *Sinanthropus* skulls. Nor is the sagittal crest of the great apes equivalent. For, as I have said before,[3] unlike the anthropoids, the

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[1] Weidenreich, 1943b.

[2] Weidenreich, 1940b, 1943b.   [3] Weidenreich, 1940b.

sagittal crest of the hominids has no connection with the temporal muscle, the line of attachment of which never reaches up to the mid line (lt, Fig. 3). The development of the sagittal crest peculiar to Skull IV is combined with an enormous bulging of the occipital torus. The torus appears as the most prominent central

They are each separated by a broad, transverse field, corresponding to the linea nuchal inferior of modern man, into a pair of superior (is) and inferior (ii) impressions. The inferior impressions are small, but deep, and are confined to either side of the occipital crest. The occipital torus is separated from the occipital planum by a deep
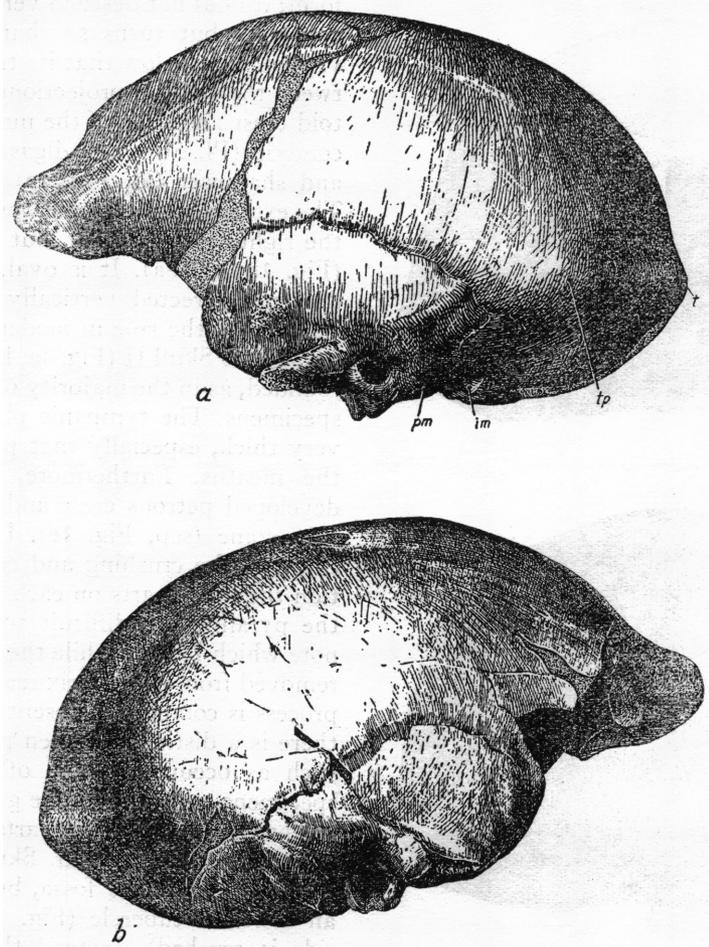
FIG. 4. *Pithecanthropus erectus* (Skull II).

section of a continuous superstructure which circles the horizontal contour of the occipital bone from one side of the supramastoid and mastoid crests to the other (t and cm, Fig. 1a, b, d). The right side has a pronounced torus angularis parietalis (tp, Fig. 1a, c, d), the left side is crushed. The crista occipitalis externa (coe, Fig. 1d and e) is a continuous, high, broad ridge terminating in a protuberance at the rim of the occipital foramen. The muscular impressions of the nuchal planum are well developed.

sulcus supratoralis (st, Fig. 1a, d) and from the nuchal planum by a sharp linea nuchae superior (ls). In *Pithecanthropus* Skull II all these special features of the occipital bone are either entirely absent or only faintly indicated. The occipital torus resembles that of Skull IV only in so far as it also is represented by a continuous ridge extending along the horizontal contour from the mastoid on one side to the opposite mastoid (Figs. 4a, b, 5b, 6a).[1] But there is neither a

[1] Weidenreich, 1940b.

distinct sulcus supratoralis nor a linea nuchae superior or inferior. We are inclined to regard these structural differences as sexual differences, particularly if they can be considered as related to muscular attachments. This point of view is supported by the fact that, in these
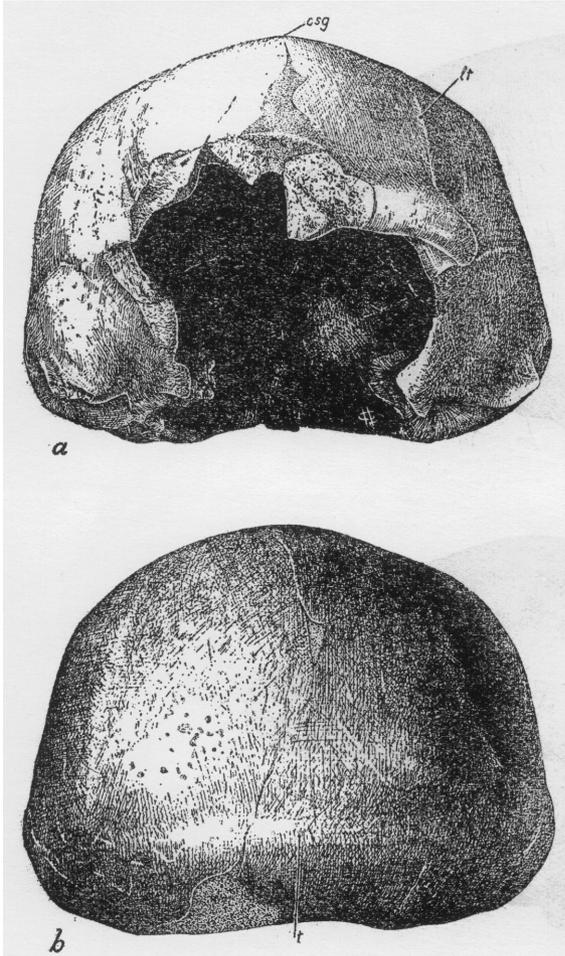
FIG. 5. *Pithecanthropus erectus* (Skull II).

features, *Sinanthropus* Skull XI is very similar to *Pithecanthropus* Skull II, while Skull XII approaches *Pithecanthropus* Skull IV.[1] This was one of the reasons why I considered *Sinanthropus* Skull XII as male and *Sinanthropus* Skull XI as female. However, in the two *Pithecanthropus* skulls the differences are much more pronounced than in the two *Sinanthropus* skulls.

There are also other important differences.

[1] Weidenreich, 1943b.

In *Pithecanthropus* Skull IV the mastoid process is very large and projects far downward (cm, Fig. 1a; pm, Fig. 1e), while in Skull II it is a small and negligible protuberance (pm, Fig. 4a). However, in Skull IV, in spite of its resemblance to that of modern man, the process exhibits its primitive character by its special form; it does not descend vertically, as in modern man, but turns so sharply inward when viewed from below that its tip lies halfway between the vertical projections of the supramastoid crest and that of the medial border of the condyle (Pl. 5b). The digastric fossa is wider and shallower (id, Fig. 1e) than in Skull II. The external auditory meatus is compressed on the right side (Fig. 1a), but intact on the left (Fig. 1b; Pl. 3a). It is oval, with the greater diameter directed vertically and slightly forward, as is the rule in modern man.[2] In *Pithecanthropus* Skull II (Fig. 4a, b) the form is more rounded, as in the majority of the *Sinanthropus* specimens. The tympanic plate of Skull IV is very thick, especially that part which borders the meatus. Furthermore, there is a well-developed petrous crest and a prominent petrous spine (scp, Fig. 1e). Unfortunately, because of the crushing and consequent dislocation the other parts on each side of the base of the pyramid are difficult to recognize. But a note which I made while the original was being removed from the matrix reads that the styloid process is completely absent and that, instead, there is a distinct foramen processus styloidei, such as occurs in some of the *Sinanthropus* specimens and in the male gorilla. In *Pithecanthropus* Skull II these parts of the temporal bone are not preserved. Skull IV has a deep, narrow, mandibular fossa, but no indication of an articular tubercle (Fig. 1e, left side; right side is crushed). Instead there is a perfectly even preglenoidal area (planum preglenoidale, plp, Fig. 1e) which extends from the rim of the fossa forward to the base of the pterygoid process (pp, Fig. 1e). The zygomatic process is broken off on either side close to the squamosal surface. Nevertheless, a "sulcus processus zygomatici," as I have called this feature,[3] is clearly recognizable, indicating that the zygomatic arc was far from the squama. There was no true postglenoidal process, but a well-developed crista postglenoidalis (cpg, Fig. 1e) was obvi-

[2] Weidenreich, 1943b.
[3] Weidenreich, 1943b.
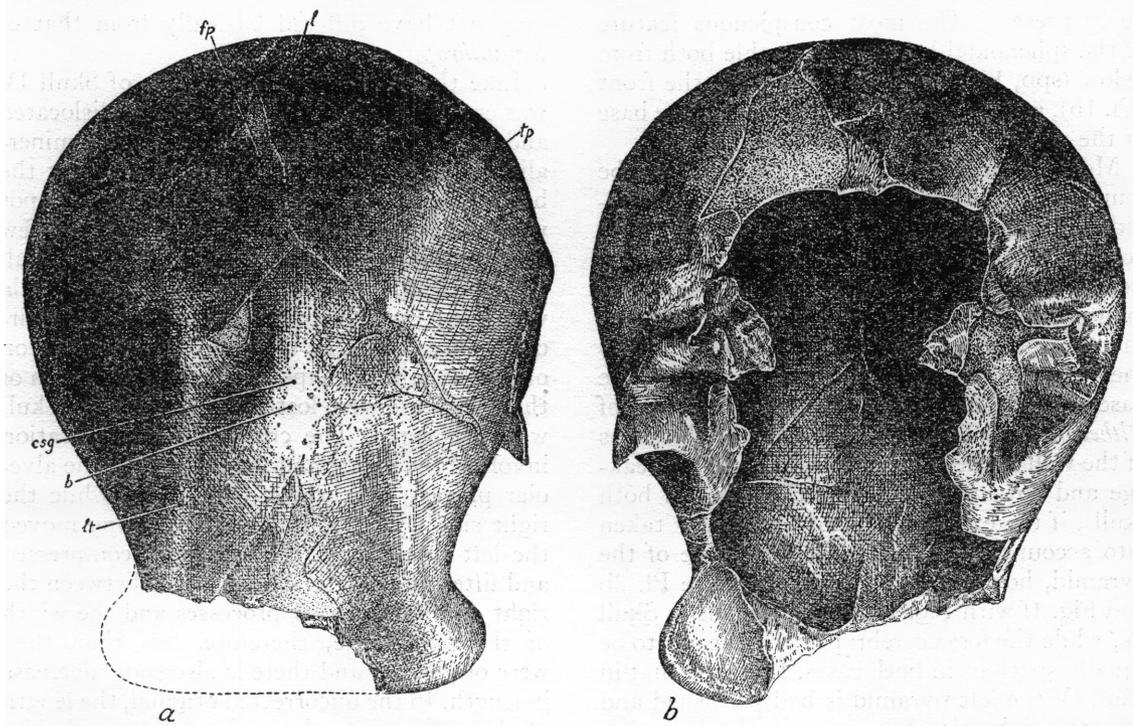
FIG. 6. *Pithecanthropus erectus* (Skull II).
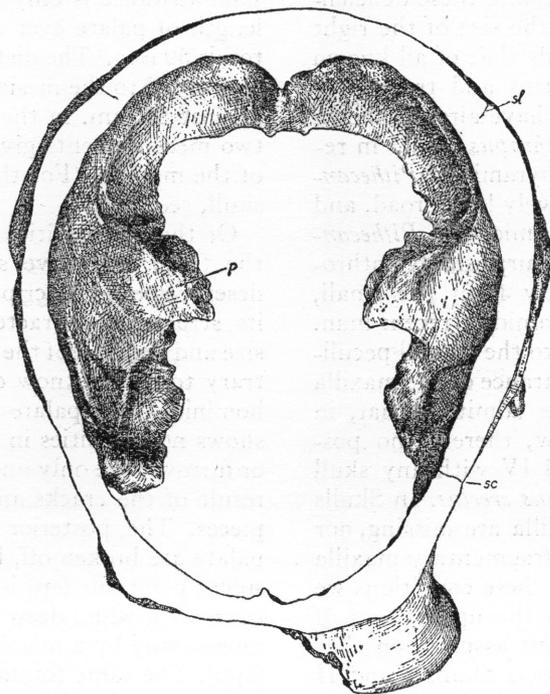
FIG. 7. *Pithecanthropus erectus* (Skull II). Horizontal section through the cast of the skull cap.

ously present. The most conspicuous feature of the sphenoidal bone, recognizable both from below (spp, Fig. 1e; Pl. 2a) and from the front (Pl. 1b), is a large sinus which occupies the base of the pterygoid process.

Most of the features described here may be found in *Pithecanthropus* Skull II or in individual *Sinanthropus* skulls, but the special character of Skull IV which determines its separation from the other is the combination of so many apparently primitive hominid features in the one specimen. Its specific difference is further evident when the cerebral surface of the base (Fig. 1f; Pl. 2b) is compared with that of *Pithecanthropus* Skull II (Fig. 7). The thickness of the wall of the brain case, laid bare by breakage and cut, may be about the same in both skulls, if the excessive size of Skull IV is taken into account. The difference in the size of the pyramid, however, is striking (compare Pl. 2b and Fig. 1f with Fig. 7); it is enormous in Skull IV, while the fossa cerebri posterior seems to be equally spacious in both cases. It is true that in Skull IV the left pyramid is badly crushed and that the right also bears traces of telescoping and dislocation. It is also true that the greater part of both pyramids and posterior fossa are missing in Skull II. But despite these deficiencies, it can be stated that the size of the right pyramid of Skull IV exceeds that of all known hominid or anthropoid forms and transcends any sexual difference. As I have already shown in my paper on the *Sinanthropus* skull,[1] in referring particularly to the pyramid of *Pithecanthropus* Skull IV, the relatively low, broad, and massive form of the pyramids of *Pithecanthropus* and *Sinanthropus* is surprisingly anthropoid-like and differs widely from the small, high, narrow, and frail pyramid of recent man.

If any doubt remains as to the special peculiarity of Skull IV, the appearance of the maxilla will remove it. It must be admitted that, in the case of the upper jaw, there is no possibility of comparing Skull IV with any skull attributed to *Pithecanthropus erectus*. In Skulls I and II the face and maxilla are missing, nor has any other complete or fragmentary maxilla been found in Java. Under these conditions we can have recourse only to the upper jaws of *Sinanthropus* under the tacit assumption that the maxilla of *Pithecanthropus* Skulls I and II

may not have differed basically from that of *Sinanthropus*.

Like the brain case, the maxilla of Skull IV was crushed, and the fragments were dislocated and afterward fixed in those positions by mineralization. This, together with the fact that the brain case was found in exactly the same spot where the maxilla had been recovered a few weeks earlier, proves that the maxilla and skull belong together. The fractures of the maxilla were fresh and not coated by matrix. This circumstance indicates that the superior portion of the face and perhaps also the front portion of the brain case were lost shortly before the skull was discovered. The crushing and dislocation involved the palate and the left side of the alveolar process (Fig. 2b, c, d; Pl. 3d), while the right side (Fig. 2a) is intact. Crushing moved the left side toward the right and compressed and lifted the palate. The distance between the right and left alveolar processes and the width of the palate are, therefore, less than they were originally, and there is also some decrease in length. In the uncorrected original, the length of the palate from the orale to the staphylion (in this case the top of the spina nasalis posterior) is 75 mm., while in the Rhodesian Skull the same distance is only 57.7 mm. The maximum length of palate ever recorded in modern man totals 59 mm.[2] The distance from the distal surface of M^3 to the mesial surface of C is 67 mm., against 58 mm. in the Rhodesian Skull. These two measurements give a good idea of the size of the maxilla. (For those of the reconstructed skull, see p. 32.)

Of the peculiarities of the palate—those of the teeth will have separate mention—three deserve special description. Two of these are in its structural character and the third in the size and position of the foramen incisivum. Contrary to all we know of both fossil and recent hominids, the palate is smooth (Pl. 3d). It shows no rugosities in the form of either ridges or furrows; the only unevenness is obviously the result of the cracks and dislocations of broken pieces. The posterior lateral portions of the palate are broken off, but on the right side the sulcus palatinus (sp) is still recognizable. It appears as a wide, deep notch, its medial border represented by a massive, irregular excrescence (tpp). The same formation is found on the left

[1] Weidenreich, 1943b.

[2] Martin, 1928.

side, but closer to the mid line, that is to say, closer to the fused sutura palatina mediana (spm). This asymmetrical location indicated that the left structure had been dislocated while the right one retained its position. Both are broken, showing an irregular surface. Nothing in any hominid or anthropoid can be compared with these formations. They have no relation to

bone must have been formed differently from that of any known hominid or anthropoid. The entrance to the canalis incisivus (fi, Fig. 2d) is a wide funnel-like opening at the nasal floor on either side of the septum. The right aperture, the smaller of the two, is more than double the size of that in modern man, whereas the left is many times larger. The palatal opening of the

TABLE 4

LINEAR MEASUREMENTS AND INDICES OF THE FACE OF *Pithecanthropus robustus* (UNRESTORED AND RESTORED) COMPARED WITH THOSE OF *Sinanthropus*, NEANDERTHALIANS, AND MODERN MAN (IN MILLIMETERS)

No. FM	Measurement	*Pithecan-thropus robustus* Unrestored	*Pithecan-thropus robustus* Restored	*Sinan-thropus* Recon-structed	Rhodesian Man	Other Neander-thal. Maximum	Wadjak II[a]	Modern Man[b] Minimum-Maximum
				LINEAR MEASUREMENTS				
11	Alveolar height	31.5	31.5	25	32	29	27?	—
23	Nasal width	36	36	30	31.1	34.5	30	Individuals: 17–36
33	Maxillo-alveolar length	75	81	64	66.7	70	62?	Individuals: 44–67
34	Maxillo-alveolar width	78	94	71	78	71	82	Individuals: 50–75
36	Ant. maxillo-alveolar width	61	63	46	55	—	48	—
37	Palatal length	75	85	52	57.7	62	—	Individuals: 40–59
38	Palatal breadth	41	53	39	48.6	50	—	Individuals: 33–48
39	Palatal height	22	14	12	19.2	—	—	Individuals: 6–21
—	Length of the upper dental arch	—	70.5	60	64	56	60	—
—	Breadth of the upper dental arch	71?	92	68	79	75	71	—
—	Upper dental length	55.5	55.5	46.5	49	48.5	54	—
—	Upper molar length	38.5	38.5	31	34	36	38	—
				INDICES				
9	Maxillo-alveolar	104	116	107.6	116.8	117.5	132.4?	Individuals: 94–154
12	Palatal	54.7	62.2	75.1	84.6	79.1	—	Racial groups: 63.6–94.6
13	Palatal height	53.6	26.4	30.7	39.5	31.4	—	Individuals: 21.0–55.0

[a] After Dubois, 1922.
[b] After Martin, 1928.

a torus palatinus; neither their form nor their location lends support to such an identification. As each excrescence is located near the posterior border of the bone, and binds the sulcus palatinus, I consider it a part of the basis of the processus pyramidalis which bridges over the sulcus and extends downward and backward to the medial lamina of the pterygoid process. If this is so, and there seems to be no other explanation, the pyramidal process of the palate

canal (Pl. 3d) lies farther in a distal direction from the orale than in modern man, a point I have elsewhere discussed at length.[1]

The height of the premaxillare (nasospinale-prosthion) is 31.5 mm. (Pl. 3b, c; Table 4); that of the Rhodesian Skull, which is noted for the extraordinary height of the alveolar portion of the maxillary, is 32 mm. In contrast to this height, the pillars of the zygomatic process

[1] Weidenreich, 1943b.

TABLE 5

MEASUREMENTS OF THE UPPER TEETH OF *Pithecanthropus robustus* (*Pithecanthropus* SKULL IV) COMPARED WITH THE MAXIMUM VALUES OF *Sinanthropus* (IN MILLIMETERS)

	I²	C			P¹			P²			M¹			M²	M³
	r	r	l	av.	r	l	av.	r	l	av.	r	l	av.	r	r
Crown:															
Height	(9.3)ᵃ	(12.5)	(13.1)	(12.8)	(8.4)	(8.7)	(8.55)	(7.5)	(8.5)	(8.0)	(6.7)	(7.0)	(6.85)	(7.7)	(7.7)
Length (mesio-distal)	10	9.5	9.5	9.5	8.2	8.5	8.35	8.2	8.5	8.35	12.1	12.3	12.25	13.6	10.8
Breadth (bucco-lingual)	10.4	11.7	11.9	11.8	12.4	12.4	12.4	12.1	12.3	12.25	13.7	13.6	13.65	15.2	14
Rectangles (length×breadth)	104	111	113	112	102	105	103.5	99	104	101.5	166	167	166.5	207	151
Root (neck):															
Length	—	7.4	7.3	7.4	6.6	6.2	6.4	6.7	6.1	6.4	10.2	10	10.1	11	9.6
Breadth	—	12.0	—	12	11.7	12.3	12.0	11.2	9.1	10.15	13.4	12.8	13.1	15.1	13.5
Sinanthropus (Maximum Values)															
Crown:															
Height	11.9	—	—	14.2	—	—	9.7	—	—	8.3	—	—	8.3	8.2	(6.4)
Length	8.3	—	—	10.5	—	—	9.2	—	—	8.9	—	—	12.1	11.1	10.1
Breadth	8.2	—	—	10.6	—	—	12.8	—	—	12.5	—	—	13.4	13.2	12.5
Rectangles	68	—	—	111	—	—	118	—	—	111	—	—	162	146	126
Root:															
Length	6.2	—	—	9.3	—	—	7.2	—	—	5.7	—	—	8.9	8.9	9.8
Breadth	8.1	—	—	11.1	—	—	12.8	—	—	10.8	—	—	13.2	12.8	12

ᵃ Figures of height in parentheses refer to worn teeth.

reach far downward. As may be observed in the intact right side (Fig. 2c; Pl. 3c), the point where the process rises from the maxillary body is only 10 mm. above the alveolar border (in the Rhodesian Skull the distance is more than 20 mm.). There is a very pronounced facial and alveolar prognathism (Fig. 2a and b; Pl. 3b). The rim of the nares is formed by a simple margo limitans, as is also the case in *Sinanthropus*. Unlike *Sinanthropus* there is neither a sulcus nor a fossa prenasalis, and there is, furthermore, no typical nasal spine. The maxillary sinus is large, but does not extend backward in the maxillary tuber (tm) which is formed by a thick and massive bone wall (Fig. 2d). On either buccal side of the alveolar process (Fig. 2a, b; Pl. 3b) are slight but distinct maxillary exostoses (em) which are also especially noticeable above the alveolar process, conditions similar to those in *Sinanthropus*.[1]

The teeth (Pl. 3b–d) are little worn, the degree of attrition ranging from approximately No. 2 to No. 3 of the scale. All show human characteristics. The canine, preserved on both sides, is small compared with anthropoid teeth, but is larger than the canine of any recent or fossil hominid. Only the largest *Sinanthropus* canine in our collection attains an equal size (Table 5 and Fig. 26a–c). It is worth noting that the breadth exceeds the length as in all hominid canines, while the opposite relative proportion is true of the anthropoids. The height of the crown cannot be determined exactly because of the attrition; it totals 12.5 mm. (right) and 13.1 mm. (left). The maximum height of the unworn *Sinanthropus* canine is 14.2 mm. The *Pithecanthropus* canine, therefore, cannot have been much higher even if it had exceeded the height of the highest known *Sinanthropus* canine. Fig. 2a and Pl. 3b show that the canine projects over the first premolar for, although the left side (Fig. 2b) is damaged, the projection is clearly seen. Of the three molars, M² is by far the largest (Pl. 3a, d; Fig. 26a; Table 5). This is obviously a simian character. Remane says:

Except for the female chimpanzee, the second molar is in most cases the biggest of the three molars. In the upper jaw it is particularly evident in gorilla.[2]

[1] Weidenreich, 1943b; see literature noted there also.
[2] Remane, 1921.

In hominids, including *Sinanthropus*, the first upper molar is the largest of the molars (Table 5 and Fig. 26b). The third molar of *Pithecanthropus* Skull IV is the smallest of the molars, but it is only a little smaller than M¹ (Fig. 25a), while this difference is much greater in *Sinanthropus* (Fig. 25b) and the other fossil and recent hominids (Fig. 25c).

The four incisors are missing, but the alveoli are preserved so that it is possible to form an opinion, based on definite grounds, as to their size, position, and the angle at which they are set. In addition to those belonging to this jaw, an isolated tooth was found at the site from which this specimen was obtained. I consider this tooth as a lateral right incisor and set it in the corresponding alveolus when the skull was being restored (Pl. 5a–c). Von Koenigswald disagrees with me in this identification. On the distal side of the tooth he found a kind of facet which he regards as a contact facet. As there is a wide diastema between the lateral incisor and the canine (see below), according to von Koenigswald, the tooth cannot be a lateral incisor, but must be a medial one. However, the crown is too small and the socket too wide for a medial incisor. Moreover, although I made a thorough examination when I had an opportunity to study the original, I did not recognize that contact facet. A final identification, therefore, must be held in abeyance until the original is again available. In any case, the size of the alveoli indicates that the medial incisors were large teeth with large crowns and long roots, whereas both the roots and crowns (Fig. 2c; Pl. 3c) of the lateral incisors were considerably smaller. The axes of the alveoli extend forward; therefore the teeth must have continued in the same prognathous direction of the naso-alveolar clivus (Fig. 2a; Pl. 3b). In other words, there was a "prodonty" of the incisors, as the canines stand almost vertically, and the direction deviates clearly from that of the incisors.

Such a divergence is in accord with another peculiarity of the jaw, so far unique among hominids. There is a wide diastema on either side between canine and lateral incisor (d, Fig. 2c; Pl. 3c, d) or, more correctly, between the canines which have been preserved and the distal walls of the alveoli of the lateral incisors. This interstice measures 6.2 mm. on the left side and 5.0 mm. on the right, but in the latter

case the border of the alveolus is slightly damaged. According to Remane's list,[1] a width of more than 5 mm. for the maxillary diastema occurs in only 49 per cent of the anthropoids and a width of more than 6 mm. occurs in only 38 per cent. Therefore, the maxillary diastema in *Pithecanthropus* Skull IV would be considered wide even when judged by the anthropoid standard.

The pattern of the upper teeth (Pl. 3d) does not differ, essentially, from that of *Sinanthropus*, except that the remains of the cingulum are less pronounced in the *Pithecanthropus* teeth than in the latter. The canine pattern shows the same arrangement and development of the crests and of the lingual surface as that I described in *Sinanthropus*[2] and the same is true of the wrinkle system of the premolars and molars. At first glance the wrinkles seem less pronounced, but when the individual teeth are compared with those of *Sinanthropus* having a corresponding degree of wear, the difference is practically nil.

B. MORPHOLOGICAL CHARACTER OF THE SKULL BASED ON THE RECONSTRUCTION

Although the reconstruction will probably have to be revised when the original is again available, the reconstructed brain case permits certain estimates which provide a basis for the comparison of *Pithecanthropus* Skull IV and *Pithecanthropus* Skulls I and II. In my paper on the *Sinanthropus* skull,[3] I listed the linear measurements, angles, and indices which indicate the gradual changes in the human brain case in the course of evolution. Since, as in *Sinanthropus*, the posterior portion of the skull base is preserved, I have chosen the basal length (nasion-opisthion line) as the comparative basis for the computation of the gradually increasing height of the brain case and of the changing position of its main landmarks which parallel this expansion. In Tables 1–4 these measurements are given for *Pithecanthropus* Skulls I and II, *Sinanthropus* (average), *Homo soloensis* (average), Neanderthalians (averages), and modern man (averages). The sequence of the individual measurements is the same as that in the original lists. For all details of that nature as well as for the estimates for *Pithecanthropus* Skull IV, the reader is referred to my earlier publication.[4]

Although the length and breadth of Skull IV were considerably greater than of Skull II, the former seems to have been lower or of about the same height as Skull II. The estimated measurements are: basi-bregmatic height, 102 mm.; auricular height, 90 mm.; calvarial height above the glabella-opisthocranion line, 49 mm.; vertex height above nasion-opisthion line, 78 mm. These measurements should be compared with 105, 89, 66, and 88 mm. for Skull II. These differences are still more striking when the corresponding length-height indices are computed. The length-total height index is 51.2 compared with 59.6; the length-auricular height index is 45.2 compared with 52.2; the calvarial height index is 24.6 compared with 35.3, and the vertex-height index is 61.1 compared with 64.2. As the brain case may have been higher than is assumed for the frontal region, these differences should not be stressed. At the lambdoid region, which was not affected by the crushing, Skull IV is lower than Skull II, as is proved by the lambda-height index of 54.1 for the former and 55.6 for the latter. The relatively greater flatness of Skull IV is also illustrated by the interporial-coronal craniogram (Fig. 3) which represents the portion of the skull which was barely affected by the injuries. The same fact can also be deduced from the narrow inclination angle of the frontal squama (Table 2, No. 3), and the narrow angle of the occipital curvature (Table 2, No. 10). The frontal angle is smaller by 10° than that of Skull II. Even if this angle is disregarded because of the doubtful character of the frontal region in the reconstruction, the angle of occipital curvature which will remain unchanged by any revision of the reconstruction is smaller by 12° than that of

[1] Remane, 1921.
[2] Weidenreich, 1937a.
[3] Weidenreich, 1943b.
[4] Weidenreich, 1943b.

Skull II. The index of occipital curvature (Table 3, No. 40) points in the same direction. It is 62.8 in Skull IV compared with 75.0 in Skull II; in other words, the occipital bone is much more curved in the mid-sagittal plane in the former skull than it is in the latter, the difference amounting to 12 index units. On the other hand, the index of parietal curvature is almost the same in both skulls (96.8 and 95.9) in contradistinction to Neanderthalians and modern man where the curvature of the parietal bone (index 93.2 and 89.4, respectively) increases as a consequence of the vertical expansion of the brain, while the curvature of the occipital bone, indicating the lowness of the skull, decreases. The curvature index of Skull IV is 62.8 compared with an average of 80.8 in modern man, making it the lowest index of any known hominid.

A conspicuous feature is the extraordinary breadth of Skull IV. In *Sinanthropus* and in some of the skulls of *Homo soloensis*, the breadth is greatest at the base of the skull, from which point it decreases gradually toward the top. In Neanderthalians and in modern man the greatest breadth is high up on the temporal squama or the parietal bone (Fig. 3).[1] In *Pithecanthropus* Skull II the greatest breadth is slightly above the base, whereas in Skull IV it is actually at the base, so that the interporial craniogram has an almost triangular form (Fig. 3). The index of lower parietal breadth (Table 3, No. 26), which expresses the relation between the breadth taken at the base (biauricular or intercristal breadth) and that at the level of the temporoparietal suture, is 80.2 in Skull IV, but 101.5 in Skull II, while it is 107.9 in modern man. Although, of course, changes in the restoration may be made when the original is at hand, these changes will hardly be important enough to affect this result decisively.

One of the most characteristic features of *Pithecanthropus* Skulls I and II is the form of the occiput as shown in vertical and basal views. The occiput is not elongated, as in *Sinanthropus*, but is short and perfectly rounded, so that it corresponds to Sergi's "sphenoides" type. This is also true of the occiput of Skull IV. Even the pronounced projection of the heavy occipital torus has no essential effect on the fundamental form of the skull (Pl. 5b).

[1] Weidenreich, 1943b.

As already indicated above, one of the most interesting characteristics of Skull IV is the position of the occipital foramen. As the basal view of the reconstruction shows (Pl. 5b), the foramen occupies the same central position as in modern man. The measurements corroborate this view. The occipital length index I (Table 3, No. 18) suggests the distance of the opisthion from the opisthocranion in proportion to the maximum length of the skull when projected to the Frankfurt Horizontal. In modern man this index is 30.6, its minimum-maximum values ranging from 25.1 to 36.9. In the anthropoids the corresponding figures are 10.0–14.1.[2] This means that, in man, the median point of the posterior margin of the occipital foramen (opisthion) lies two to three and a half times farther forward from the hindmost landmark of the brain case (opisthocranion) than it does in the great apes. In *Pithecanthropus* Skull IV the index is 26.6. This still falls within the normal range of modern man although close to its lower limits and far beyond the upper limit of the range in anthropoids. In Skull II the index is 24.1. The occipital length index II indicates the same distance as index I but, instead of referring to the maximum length of the skull, it is related to the nasion-opisthion line prolonged beyond the opisthion to the base of the opisthocranion. This index is −28.3 in Skull IV, against an average of −21.8 in modern man, the range being from −18.0 to −29.8. In other words, the opisthion lies farther to the front in the majority of modern human skulls. The average index of the anthropoids is −6.4 with a range from −5.9 to −7.2. In *Pithecanthropus* Skull II, index II is −22.5; in *Sinanthropus* the index is −24.0; in *Homo soloensis* the range is from −24.5 to −33.0. These high indices revealed in *Homo soloensis*, surpassing the upper limit of modern man, are partly the result of the extraordinary development of the occipital torus. This development increases the distance between the opisthion and the opisthocranion, giving a false impression of the actual condition. Such a torus, which seemingly carries the "opisthocranion" far backward, never occurs in modern man. In any case, *Pithecanthropus* Skull IV clearly shows that the occipital foramen occupies a central position in spite of the manifold primitive characters of the skull.

[2] Weidenreich, 1943b.

Therefore, this position must have been attained in a very early stage of human evolution.

I have restricted the measurements of the reconstructed face to those I consider reliable and have omitted those which refer solely to the reconstructed portions (Table 4). This restriction is all the more justified because no facial bones of Skulls I and II are preserved with which the restored parts can be compared. There remain, then, those measurements concerned with the inferior part of the nose, the alveolar process, and the dental arch. In these cases, too, the measurements, especially where the breadth is concerned, must be regarded with some reservation. To give a fair idea of the dimensions, I have added a separate column to Table 4 which contains the measurements of the maxilla in its compressed condition as it was found. These figures represent, as it were, minimum values, while those of the reconstructed upper jaw give the greatest possible breadths. The width of the anterior nares (36 mm.) is greater than in any other of the known fossil hominids and reaches the uppermost limit so far recorded in recent man. The alveolar height (nasospinale-prosthion) is also very great (31.5 mm.) and is almost the same as that of the Rhodesian Skull in which the facial height exceeds that of the entire Neanderthalian group. The maxillo-alveolar length of the restored face is 81 mm.; unrestored it is 75 mm. Even if only the latter measurement is taken into account, the length far exceeds that of fossil and recent hominids. The maxilla-alveolar width of the restored bone—and it cannot be far from the normal condition—is 94 mm.; that of the compressed bone is 78 mm. If an error of 5 mm. is allowed for the reconstruction, the width amounts to 89 mm. This is a far greater breadth than has ever been found in any hominid. The maxilla of the Wadjak Skull II, which exceeds all fossil and recent forms in breadth, is considerably narrower (82 mm.).

The extraordinary breadth of the maxilla of Skull IV can also be deduced from the so-called anterior maxillo-alveolar width—the distances between the buccal surfaces of the alveolar process, mesial to the canine, on either side. This width is 61 mm. in the non-restored maxilla and 63 mm. in the restored one. In the Rhodesian Skull it is only 55 mm. and in the Wadjak Skull II not over 48 mm. The figures for the palatal length and breadth are correspondingly high. This is particularly true of the length, which exceeds the length of the Rhodesian Skull by 18 mm., even in the non-restored palate (75 mm.).

The indices computed on the basis of the non-restored maxilla show that Skull IV was dolichuranic or close to the lower mark of mesurany; the skull, in any case, was leptostaphyline. The leptostaphyline index (54.7 restored; 62.2 mm. non-restored) falls within the range of the anthropoids (34.5 to 62.5) as well as the hominids, but is closer to the upper level of the former group.

Of the non-metrical features shown in the reconstruction of the skull, one, particularly, deserves mention. This feature is the curvature of the anterior portion of the temporal squama. This has never before been found in any fossil hominid but occurs in anthropoids, being more pronounced in the big skulls than in the small ones. In modern man and in all known fossil hominids, this squama extends, for its total length, in an almost straight sagittal plane from the mastoid portion to the sphenosquamosal suture. In anthropoids, the squama is curved, the curve being accentuated as it approaches the temporal fossa. In other words, its anterior portion turns medially toward the lateral wall of the fossa and so emphasizes the postorbital constriction of the skull. In Skull IV the inward curve is so pronounced that the squama seems to bulge from behind into the temporal fossa (Pl. 5b).

C. MORPHOLOGICAL CHARACTER OF SKULL IV

In the two preceding sections, a description of the peculiarities of Skull IV has been given as far as is possible in its present condition. Doubtless the general character of the brain case is the same as that of Skulls I and II. Some deviations scarcely go beyond the usual sex differences. For this reason I first regarded Skull IV as that of a male and Skulls I and II as those of females. But there are other structures which cannot be forced into such a scheme. This holds true especially for the maxilla; both palate and teeth have features

TABLE 6

Measurements of the Body of the Mandibles of Java, *Sinanthropus*, Neanderthalians, Recent Man, Recent and Fossil Anthropoids (in millimeters)

Column groups: **Java Mandibles** (Meganthropus – Kedung Brubus); ***Sinanthropus pekinensis*** (A II – Average); **Neanderthaloid groups** (Heidelberg – Average); **Recent Man (after Keiter)** (Bushman – Average); **Fossil Anthropoids** (Paranthropus robustus – Average); **Recent Anthropoids** (Gorilla – Chimpanzee).

	Meganthropus	Sangiran 1939	Pithecanthropus B	Kedung Brubus	A II	G I	H I	K I	M	Average	Heidelberg	Naulette	Malarnaud	Spy I	La Quina	Krapina G	Krapina H	Ehringsdorf ad.	Tabūn I	Skhūl V	Average	Bushman	Australian	Melanesian	Average	Paranthropus robustus	Sivapithecus himalayensis	Dryopithecus fontani	Dryopithecus pilgrimi[a]	Average	Gorilla Min.	Gorilla Max.	Gorilla Av.	Orang Min.	Orang Max.	Orang Av.	Piltdown[b]	Chimp Min.	Chimp Max.	Chimp Av.
A. Thickness at the vertical level of:																																								
1. Symphysis	25.5	19	16.4?	—	13.5?	13.7?	14	12.7	14	13.6	16.7	14.6	12.9	15.7	18.1?	16.0	16.8	13.6	13.2	15.5	15.3	11.8	13.8	13.8	13.1	22.8	17	20.5	20.8	18.5	23	31	26.4	15	25.2	20.4	14.5	15	17.5	16.5
2. Mental foramen	28	19.3	16.5	16.3	15.2	16.4	15.4	16	14.7	15.5	17.5	15.2	14.5	14.6	15.3	16.0	14.8	14.7	15	13.2	15.1	10.2	12	11.8	11.3	24	17	15	15.2	17.8	19	26.2	21.3	16	22	18.3	15.5	14.5	17	15.5
3. Between M_2 and M_3	26.3	20.3	17.8	—	15.5	19.6	15.4	18.5	15.8	16.9	21.4	17.5	18.3	15.4	15.7	16.5	14	15.5	15.2	13	16.2	17	15.5	—	—	27.5	20.5	16.8	17.8	18.1	21.2	28.3	24.7	16	27	21.3	18	15	19	17.3
Average	26.6	19.5	16.9	—	14.7	16.6	14.9	15.7	14.8	15.7	18.5	16.4	15.2	15.2	16.4	16.4	15.2	14.6	14.5	13.9	15.5	13	13.8	—	—	24.8	18.2	17.4	17.9	19.4	—	—	24.1	—	—	20	16	—	—	16.4
B. Height at the vertical level of:																																							
1. Symphysis	47	(38.2)	42.2?	—	—	40.7?	32.5	33.1	28.8	33.8	36	32.3	29.2	36.4	33.2?	30.5	40	32	30.3	36.5	34.2	32.3	30.6	29.5	37.4	—	39?	—	42.8	—	54	73	60.5	40.5	68	55.3	46	34	45	39
2. Mental foramen	48	38.5?	35	25.6	25.6	34	26	27.4	25.2	27.6	35.8	27	25.5	28.7	35?	29.2	34.3	30.5	27.5	36.3	31.1	30	26.3	28.5	28.3	31?	37	34.5?	31.7	33.5	39	49	43	35.5	42	39.5	31	29	30	29.7
3. Between M_2 and M_3	45	30?	31	—	—	32.8	25	25.3	25.3	27.5	31	24.5	25.4	32.1	31.4	29.5	34	28.4	26.2	34.5	28.8	21.8	25.6	—	—	29	31	35	31.7	36	—	—	45	38	40	39	29.5	26	27	26.3
Average	46.7	35.6	36.1	—	—	35.8	27.8	28.6	27	29.6	34.3	27.9	26.7	32.4	33.2	29.7	36.1	30.3	28	36.3	31.4	28	27.5	—	—	—	35.7	—	35.5	—	—	—	47.2	—	—	44.6	35.5	—	—	31.7
C. Circumference at the vertical level of:																																							
1. Symphysis	120	—	103?	—	—	98?	81	79	(68)	86	90	82	75	89	?	79	90?	?	—	—	84.2	—	76.3	72.6	—	—	103.2	—	107	—	112	165	145	103	156	129	102	83	104	95
2. Mental foramen	131	105	89	79	78	86	77	75	(65)	79	92	74	75	85	79	80	82	75	—	—	80.3	—	—	—	—	90	90?	87?	85	88	99	121	111.5	92	117	103	86	71	74	72.3
3. Between M_2 and M_3	122?	—	85	—	—	93	76	74	71?	78.5	88	69	72	76	80	72	?	73	—	—	75.7	—	—	—	—	102?	90?	85	81	89.5	96	112	105	92	112	99	83	70	75	72
Average	124.3	—	92.3	—	—	92.3	78	76	—	81.2	90	75	74	83	—	77	72	—	—	—	80.0	—	—	—	—	—	94.4	—	—	91	—	—	119	—	—	110	90.3	—	—	79.8
D. Index of robustness I																																							
1. Symphysis	54.3	—	41.5	—	—	33.6	43.1	38.3	48.6	40.9	46.4	45.3	44.2	43.2	54.5	52.4	42	42.5	43.6	42.4	45.6	36.5	45.2	46.8	42.8	77?	43.7	—	48.6	—	33	47.8	44.4	36.1	37.4	36.9	31.5	37.7	46	41.6
2. Mental foramen	58.4	50.2	47.2	63.6	59.4	48.3	58.4	58.4	57.8	56.4	48.6	56.3	56.9	50.8	43.7	54.8	43.2	48.2	54.5	36.7	49.4	34.0	45.6	41.4	40.3	—	43.6	43.4	47.4	—	40.4	64	49.4	36.9	53.6	46.1	50	49.2	50	49.5
3. Between M_2 and M_3	58.4	—	57.4	—	—	59.7	61.6	73.2	58.5	63.3	69	71.4	72.1	48	50	55.8	41.2	54.6	57.6	37.7	55.8	78	60.6	—	—	94.5	—	—	66.3	48	49.3	72.2	64.9	42.1	67.5	54.5	61	55.5	75	66.6
Average	57	—	48.7	—	—	47.2	54.4	56.6	55	53.5	54.6	57.7	56.7	47.3	49.4	54.3	42.1	48.4	51.9	38.9	50.3	49.5	50.5	—	—	94.5	—	—	—	51.9	—	—	52.9	—	—	45.5	47.5	—	—	52.6
E. Index of robustness II																																							
1. Symphysis	21.2	—	15.9	—	—	14	17.3	16.1	—	15.8	18.5	17.8	17.2	17.6	—	20.1	18.7	—	—	—	18.3	—	18.1	19	—	—	16.5	—	19.4	—	14.7	20.6	18.2	14.1	16.2	15.4	14.2	16.4	18.1	17.3
2. Mental foramen	21.4	18.3	18.6	20.6	19.5	19.1	20	21.3	—	20	19.1	20.5	19.4	17.2	19.4	20	18.1	—	19.6	—	19.2	—	—	—	—	26.7?	18.9	17.2	17.8	—	16.5	21.8	19.1	15.8	18.8	17.7	18	20.4	23	21.4
3. Between M_2 and M_3	21.5	—	20.9	—	—	21.1	20.3	25	22.3	22.2	24.3	25.2	25.2	20.1	19.6	22.9	—	21.3	—	—	22.6	—	—	—	—	27	22.8	19.8	—	—	19.8	26.7	23.5	17.2	24.1	21.4	21.7	21	26	24.3
Average	21.4	—	18.5	—	—	18.1	19.2	20.8	20	19.3	20.6	21.2	20.6	18.3	—	21	—	21.3	—	—	20	—	—	—	—	27	22.8	19.8	—	20	—	—	20.3	—	—	18.1	17.9	—	—	24.3

[a] After Hellman's reconstruction. [b] After McGregor's reconstruction.

which are more primitive and simian-like than are to be expected in such a relatively advanced brain case as that represented by each of the "female" skulls. All the peculiarities of the brain case, those eventually fitting into a sex pattern, as well as those which lie outside that interpretation, point in one direction: they indicate the same course as that followed by evolutionary steps. Moreover, taking into account the fact that the trend toward gigantic proportions on the part of early hominids in Java has in the meantime been proved by the discovery of *Meganthropus* (see p. 52), it seems justifiable to separate the *Pithecanthropus* type represented by Skull IV from the *Pithecanthropus* type represented by Skulls I and II, and to assume that Skull IV represents a new group. For

this more robust and primitive group I propose the name *Pithecanthropus robustus*. I do not think it justifiable to discard the name *Pithecanthropus* for this type entirely, for I believe that there is a close relationship between the two groups which will, in all probability, be revealed by future discoveries. On the other hand, I do not wish to have the change of name interpreted in a strictly taxonomic sense. In my paper on the *Sinanthropus* skull[1] I discussed the problem of nomenclature as it appears in the light of its history in paleoanthropology. I shall revert to this question later in discussing the whole *Pithecanthropus* problem in the light of the latest discoveries.

[1] Weidenreich, 1943b.

III. MORPHOLOGICAL CHARACTER OF THE SANGIRAN MANDIBLE OF 1941, *MEGANTHROPUS PALAEOJAVANICUS* VON KOENIGSWALD

As MENTIONED BEFORE, the *Pithecanthropus* Mandible B still awaits description. I do not intend to describe it, but will leave it for Dr. von Koenigswald, confining myself to a description of the two latest discoveries. Since, however, this cannot be done without comparing them with the Mandible B, attributed to *Pithecanthropus*, I must in the following pages refer to this specimen also.[1]

The 1941 mandible consists of a fragment of the right side of the body extending from about the symphysis to the level of the distal end of M_2 approximately (Pl. 6), measured at the base. The alveolar portion is broken off to a greater extent, both in the frontal and the molar region, so that only P_1, P_2, and M_1 are preserved; they are still *in situ*. The alveolus of the canine is partly preserved (Pl. 6, a2, b5c), that is, the entire bottom, the distal wall, the greater part of the lingual wall, and the part of the buccal wall immediately adjacent to the distal wall. The upper portion of the alveolus is missing. The septum between P_1 and C is also broken off so that the upper moiety of the mesial surface of the root of P_1 is exposed. In a mesial-lingual position in relation to the mesial wall of the canine-alveolus is a small hole which re-sembles the bottom of the alveolus of the lateral incisor, but may be the opening of a vertical, vascular canal, as those canals are sometimes found near the lingual border of the alveolar process. More mesially the break drops down almost vertically to the base (Pl. 6, a1, a2, b1, b2). This break corresponds very closely indeed to a mid-sagittal section through the symphysis. The distal breakage of the fragment begins at the distal end of M_1, exposing the surface of the root in almost its entire length (Pl. 5c; Pl. 6, a2, b2). Beyond this, the break continues downward in an irregular slope in a distal direction. In addition, the lingual surface of the bone medial to M_1 is broken off from the upper border of the alveolar process down to below the middle so that the lingual surface of the posterior root, as well as the upper part of the anterior root is exposed (Pl. 6, a1, a2, b1, b2). There is also an indication of the mandibular canal at the distal break of the fragment (cm, Pl. 5c).

Since only the cast is at my disposal, I cannot describe the mineralization of the bone or the character of the internal structure exposed at the broken ends of the fragments. The cast is colored a rather dark brown.

A. SIZE

The most surprising peculiarity of the mandible is its size, particularly its thickness. At the three levels where this thickness can be measured, i.e., symphysis, mental foramen, and interstice between M_2 and M_3, the thickness is 25.5 mm., 28 mm., and 26.3 mm., respectively. As Table 6 shows, the average thickness of 26.6 mm. surpasses that of all known hominids and anthropoids. Only large male gorillas surpass the thickness of the fragment at the symphysis and at the inter-molar level. But there is a great and decided difference. As will be shown later, the configuration of the symphysis of *Meganthropus* deviates in principle from that of the gorilla and the other anthropoids. In these the greatest thickness of the symphysis falls above the fossa genioglossi (Fig. 12b–d) or, in other words, on the torus transversus superior or the planum alveolare. In *Meganthropus*, as in hominids (Fig. 12k–p), this thickness falls below that fossa, that is to say, on the torus transversus inferior or the so-called "Basal-platte." The following measurements demonstrate the differences:

THICKNESS, TORUS TRANSVERSUS	*Megan-thropus*	MALE GORILLA
Superior	25.0	26.2
Inferior	25.5	19.3

[1] For illustrations of the Mandible B see Fig. 8 and Pl. 8d.

Size and robustness of the mandible are usually expressed by the "index of robustness" which, according to Topinard, represents the proportion between the height and thickness of the body at the level of the mental foramen.[1] However, this measurement gives an insufficient conception of the real dimensions, since it refers only to the middle of the body and disregards the symphyseal as well as the molar regions. It is best to complete the measurements by adding the thickness of both these regions as was done in Table 6. But even with this correction the index is of little value. As Table 6, D, shows, the "index of robustness" at the level of the mental foramen is 58.4 in *Meganthropus*. That is the same figure as in the *Sinanthropus* mandibles H I and K I, and almost the same as in the Neanderthalian mandibles of Malarnaud, La Naulette, and Tabūn I, none of which can be considered a match for *Meganthropus*. The reason for the similarity of the indices, despite the obvious differences in size, is that the index expresses the relation between height and thickness but does not give the absolute value of the height. If the body of the mandible is low, the index is high, regardless of thickness. In the cases cited above, with the same index, the height of the mandible of Malarnaud is 25.5 mm., that of La Naulette, 27.0 mm., and that of Tabūn I, 27.5 mm., as against the 48 mm. of *Meganthropus*. If the height of these mandibles were the same as that of *Meganthropus*, then their indices would drop to 18.2, 15.6, and 16.0, respectively, compared with 58.4.

Another peculiarity of *Meganthropus* is that the body of the mandible has a uniform thickness. It is true that the maximum thickness is at the foramen mentale level; but it decreases only very slightly toward the third molar and again toward the symphysis. (See Table 6, A.) In *Sinanthropus*, by far the greatest thickness is reached at the molar level; this is also true of all hominids and anthropoids, except for the gorilla, where the greatest thickness is always at the symphysis. Yet in all these cases the differences between the levels is much more pronounced than in *Meganthropus*. The mean thickness of the three levels totals 26.6 mm. in the latter. The average thickness of the *Sinanthropus* mandibles is only 59 per cent of that

[1] Topinard, 1886.

figure (15.7), and the same is true of the Neanderthalians (average 15.5); the Heidelberg mandible (the thickest hominid jaw so far known) attains 18.5 or 69.6 per cent of the thickness of the Java mandible, while the mandible of modern man is only about 50 per cent.

Uniformity of the thickness is associated with a similar regularity in the circumference, particularly at the foramen mentale level. As will be shown in the description of the buccal and lingual surfaces, these, especially the former, are very evenly rounded and are not sunken as in hominids. The circumference is correspondingly large. With a circumference of 131 mm. at the foramen mentale level, *Meganthropus* far surpasses the largest available male gorilla, in which the circumference does not exceed 121 mm. The circumference of 131 mm. is 43 per cent greater than that of the Heidelberg mandible (92 mm.). The circumference of *Meganthropus* at the symphyseal level totals 120 mm., which is a little less than the circumference at the foramen mentale level. In *Sinanthropus* and the other fossil hominids the circumference at the symphyseal level is distinctly greater than that at the level of the foramen mentale. At the symphyseal level *Sinanthropus* averages 86 mm. and the Neanderthalians 84.2 mm., against 79.0 and 80.3 mm. at the foramen mentale level; the corresponding figures for *Meganthropus* are 131 and 120 mm., respectively. The difference is still more pronounced in fossil and recent anthropoids, the gorilla average being 145 mm. at the symphysis, against 115 mm. at the foramen mentale. The reason is that in every case but in *Meganthropus* the height of the body is greatest at the symphysis. The upper border of its alveolar process, it is true, rises steadily toward the symphyseal region, but the lower border of the mandible is correspondingly carved out, because of the formation of the so-called incisura submentalis (see p. 45) which takes more from the height than this dimension gains from the rise of the alveolar border. The total symphyseal height of *Meganthropus* is 46 mm. as against 48 mm. at the foramen mentale level. Although this height surpasses all like measurements of hominid mandibles, it is far below the corresponding values for gorilla and orang, the average of which is 60.5 and 52.2 mm., respectively. (See Table 6, B.)

B. SURFACES

1. BUCCAL SURFACE

Pl. 6, a1, b1

In all hominid mandibles, fossil and recent alike, the buccal surface shows a well-carved relief in which several characteristic features can be distinguished. Extending from back to front is the so-called "prominentia lateralis" which is most pronounced where the anterior border of the ramus meets the body and which is, in reality, simply the continuation of the "oblique line" of the ramus to the buccal surface. When well developed, this eminence divides into an upper and a lower branch. The upper one sweeps forward and ends near the mental foramen; the lower one occupies the entire lower margin. I designated the upper branch "torus lateralis superior,"[1] the lower one "torus marginalis," and the slight furrow which separates both tori has been named "sulcus intertoralis." The development of this relief shows great variability. It is very distinct, as in *Sinanthropus*, in *Pithecanthropus* Mandible B (Fig. 8a), and in the Heidelberg jaw (Pl. 7, b1), or it can be more or less effaced as in a prehistoric mandible shown in Fig. 2 of my paper on the *Sinanthropus* mandible.[2] In *Meganthropus* the prominentia lateralis region is missing, and only that of the "torus lateralis" is preserved. But there is no eminence which can be identified with this particular region for the simple reason that the whole surface bulges outward and continues into the lower margin with no such special differentiations as torus marginalis or sulcus intertoralis. The lateral bulge only subsides toward the teeth, but there is no distinct "sulcus extramolaris." The conditions recall those found occasionally in the gorilla or orang-utan, the only difference being that, in most of the latter cases, the torus marginalis remains recognizable, to a certain extent at least. The general bulge continues without any demarcations into the lower surface. There is only a slight depression below the mental foramen and a small, narrow elevation below this depression which may be an accidental character since it has no analogy in hominid or anthropoid mandibles. Neither is there a

[1] Weidenreich, 1936.
[2] Weidenreich, 1936.

marked relief in the chin region. There is no tuberculum marginale anterius, or any vestige of a tuberculum symphyseos, such as is suggested in the *Sinanthropus* mandible[3] and in the Heidelberg mandible (cf. Pl. 7, a1 and b1).

The mental foramen is of special interest. In contrast to the multiplicity in *Sinanthropus*, the *Pithecanthropus* Mandible B (Fig. 8a), and the Heidelberg jaw, it consists of a single opening. This opening measures 4.5 mm. in mesio-distal direction and 2.9 mm. in the vertical one. Its size, therefore, exceeds that of modern man to a considerable degree, but it is distinctly smaller than that of male gorillas which have much larger apertures. According to Schulz[4] the length of the aperture varies from 1.5 mm. to 6.0 mm. in modern man, with an average of 2.0 or 3.0 mm., according to racial groups. Bünte and Moral[5] and Schulz state that the aperture in modern man is directed backward and upward in the majority of cases, while, according to the first authors, it faces forward in anthropoids. The first statement is true, but not the second. There are cases in gorilla, orang-utan, and chimpanzee in which the aperture has a forward direction, but in about an equal number its direction is sidewise, and there are also cases in which it leads backward as it does in modern man. In *Meganthropus* the aperture itself leads directly sidewise, and there is a slight, short furrow extending from the posterior rim of the aperture backward and slightly downward toward the surface.

The foramen is in line with the interstice between the second premolar and the first molar, but closer to the premolar. It is so located in only about 32 per cent of modern men, according to Schulz' figures.[6] Simonton[7] found the most constant position in gorilla (41 per cent), orang-utan (36 per cent), and chimpanzee (50 per cent) to be in line with the second premolar. More important than the longitudinal position of the mental foramen is its vertical location in relation to the distance between the alveolar and basal planes of the

[3] Weidenreich, 1936, Fig. 4, p. 2.
[4] Schulz, 1933.
[5] Bünte and Moral, 1910.
[6] Schulz, 1933.
[7] Simonton, 1923.

mandible. The course of the mandibular canal follows approximately the division between the basal and the alveolar portions of the body, as shown in a previous paper on the human chin

latter distance the greater the alveolar portion and the smaller the basal portion, and conversely. The vertical distance of the foramen from the alveolar plane in percentage of the
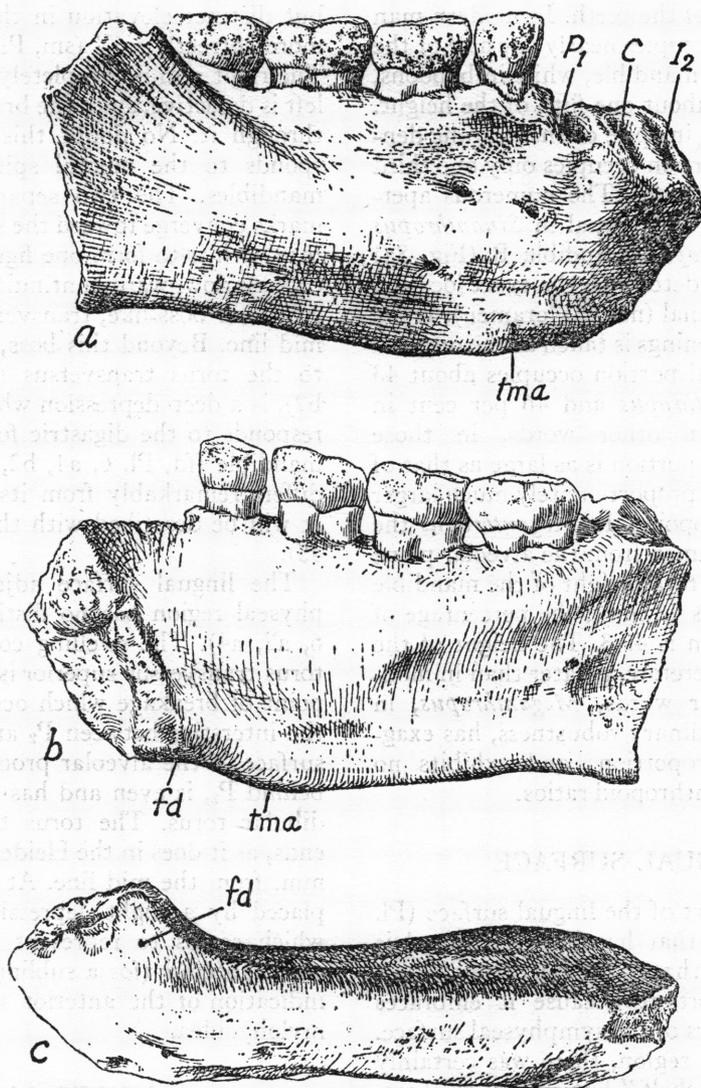
FIG. 8. *Pithecanthropus* Mandible B.

and its development.[1] The vertical distance of the mental foramen (the anterior termination of this canal) from the lower margin indicates the height of the basal portion, while its distance from the alveolar plane marks the height of the alveolar portion. The greater the

total height of the body at the same level is as follows: in recent man (average of all races) it is 53 per cent; in anthropoids the distance is greater and totals 67 per cent; in the Cercopithecidae it reaches 78.6 per cent.[2] The figures for the basal portions are, therefore, 46.6 per

[1] Weidenreich, 1934.

[2] Weidenreich, 1934, 42.

cent, 32.5 per cent, and 21.4 per cent, respectively. It follows from these figures that the larger the teeth are in proportion to the entire size of the jaw, the larger is the part of the mandible formed by the alveolar portion which includes the roots of the teeth. In modern man the basal portion occupies nearly one half of the total height of the mandible, while in baboons, for example, only about one fifth of the height. In the anthropoids, in spite of their strong dentition, the basal portion occupies only one third of the mandibular body. The numerous apertures of the mandibular canal in *Sinanthropus* and in *Pithecanthropus* Mandible B (Fig. 8a) make it difficult to determine the exact location of the end of the canal (mental foramen). If the center of all the openings is taken as the measuring point, the basal portion occupies about 43 per cent of *Sinanthropus* and 46 per cent in *Pithecanthropus*. In other words, in those hominids the basal portion is as large as that of modern man and is proportionately much larger than it is in anthropoids. In *Meganthropus* the distance of the foramen from the alveolar plane is 23.7 mm. As the total height of the mandible at the same level is 48 mm., the percentage of the alveolar portion is 49.3. The height of the basal portion is, therefore, greater than in modern man. In other words, *Meganthropus*, in spite of its extraordinary robustness, has exaggerated human proportions and exhibits no tendency toward anthropoid ratios.

2. LINGUAL SURFACE

Although the part of the lingual surface (Pl. 5c; Pl. 6, a2, b2) that has been preserved is much smaller than that of the buccal surface, it is extremely important because it embraces about three quarters of the symphyseal surface. To begin with this region, there was certainly no typical "simian shelf," but a planum alveolare continues into a very slightly developed torus transversus superior (see also Pl. 8a). This torus is less pronounced than in the Heidelberg jaw (see Pl. 8b); it resembles the conditions of *Sinanthropus* and the *Pithecanthropus* Mandible B (Fig. 8b). Immediately below the torus is a distinct fossa genioglossi (fg, Pl. 5c; Pl. 6, b2). The pit is shallow, much flatter than in the Heidelberg jaw, but more pronounced than in *Sinanthropus* H I. On the superior area of this

niche are two foramina (fss, Pl. 5c), side by side, the left one being only about half the size of the right. Through these foramina vessels enter the bone. The inferior end of the fossa genioglossi has a very remarkable feature, a low but distinct elevation in the shape of a V, or, more correctly, a Y (sm, Pl. 5c; Pl. 6, b2, b3). The right arm is completely preserved, but the left is defective, since the break in the bone cuts through it. No doubt this excrescence corresponds to the mental spine of the hominid mandibles. The two separate, upper, V-like marks converge toward the single lower one and fuse with it to form one figure. The single arm extends downward, continuing into a ridge which crosses a boss-like, transverse elevation in the mid line. Beyond this boss, which corresponds to the torus transversus inferior (tti, Pl. 6, b2), is a deep depression which apparently corresponds to the digastric fossa of the hominid mandible (fd, Pl. 6, a4, b2, b4; Pl. 8, a1), but differs remarkably from its usual appearance. It will be described with the lower margin (p. 45).

The lingual surface adjacent to the symphyseal region has no distinctive feature (Pl. 6, a2, a4). The swelling corresponding to the torus transversus superior is recognizable to the point of breakage which occurs at the level of the interstice between P_2 and M_1. The lingual surface of the alveolar process, preserved only behind P_2, is even and has no trace of a mandibular torus. The torus transversus inferior ends, as it does in the Heidelberg jaw, about 10 mm. from the mid line. At that point it is replaced by a slight depression (fsa, Pl. 6, b2) which seems to represent the fossa subalveolaris anterior (fossa sublingualis). There is no indication of the anterior section of the linea mylohyoidea.

3. LOWER MARGIN
Pl. 6, a4, b4

The lower margin of the modern human mandible is characterized by a narrow edge, sometimes sharp, sometimes obtuse, which extends from the level of M_2 to the symphysis, widening toward the chin region and thus making space for an oblong, flat area (fossa digastrica) into which the anterior belly of the digastric muscle is inserted.

Meganthropus differs widely from this picture and from that of all known hominids (cf. Pl. 7, a4). Instead of the narrow edge, a broad rounded surface extends over the total length of the fragment up to the symphysis. A rounded swelling is situated at the point where the lower margin continues into the lingual surface (tfd, Pl. 6, a4, b2, b4; Pl. 7, a4; Pl. 8, a1), at the point where the beginning of the digastric fossa would be expected. The tubercle marks the apex of a triangular slightly concave area (fd, Pl. 6, b2, b4) which is, however, not located on the lower margin itself, but on the lingual side. The area extends forward to the mid line where it ends with a slight crest, the continuation of the lower arm of the mental spine described above. The dimensions of the triangle are: length of the base (along the symphyseal edge), 12 mm.; outer side (lower margin), 16 mm.; inner side (lingual surface), 15.5 mm. This area, marking the limit between the lower and lingual surfaces, apparently corresponds to the digastric fossa of recent man.

4. TEETH

Pl. 6, a1, a2, a3, b1, b2, b3, b5

As mentioned earlier, P_1, P_2, and M_1 are preserved, together with their crowns and roots, *in situ*. Since the alveolar border is broken off, except for the lingual side of P_2, the roots are much exposed. This is particularly true of the mesial and lingual surfaces of P_1 (Pl. 6, a2, ba). The crowns are worn; the most worn is that of M_1, the least worn that of P_1. The degree of attrition as expressed in numerals[1] is 2–3 for the two premolars and 5 for M_1.

A. CANINE

The canine is missing, but the greater part of the alveolus of its root is preserved (c, Pl. 6, b2, b3, b5) so that, on this evidence, an opinion may be given as to the dimensions and shape of the canine root. An endocast of the alveolus gives a fairly exact idea of the lower half of the root; most surprising is its small size, particularly in mesio-distal direction, not only absolutely, but in proportion to the enormous size of the mandible. The height of the root, from its tip to the lower border of the enamel, was certainly not more than 20 mm. The breadth

[1] Weidenreich, 1937a.

(bucco-lingual diameter), taken at the upper end of the fracture, which may correspond to about the middle of the height, was not more than 10.5 mm., while the length (mesio-distal diameter) at the same level did not exceed 6.6 mm. The length-breadth index of the lower half of the root was, therefore, 64.2. These dimensions and their ratio are about the same as those found in the canines of male *Sinanthropus*. In *Pithecanthropus* (Mandible B), where the only part of the canine preserved is also the lower half of the alveolus (Pl. 8d; Fig. 8a), the breadth, length, and index are a little smaller: 9.5 mm., 5.0 mm., and 57.8 mm., respectively. The small size of the root and its marked compression in mesio-distal direction are characteristic features of the human canine. In all three anthropoids, regardless of sex, the two dimensions are greater and, although the breadth of the root exceeds the length, the length is relatively much greater than in the hominids, and the index, therefore, approaches 80.

Compared with *Sinanthropus*, the canine root of *Meganthropus* is more gracile and does not have a knob-like thickening at its tip. The distal surface, like that of *Sinanthropus*, had a longitudinal furrow along the entire height of the root, indicated by a distinct ridge along the alveolus wall. Whether or not there was also such a furrow at the mesial surface, as is the case in *Sinanthropus*, cannot be determined, since the mesial alveolus wall is broken off.

There is no definite indication as to the size and form of the crown of the canine. From the size and form of the root it can be assumed that it was small and that its bucco-lingual diameter (breadth) was greater than its mesio-distal one (length). In the six measurable cases of *Sinanthropus*, the average length is 8.6 mm. and the average breadth, 9.1 mm. Therefore, there is reason to assume that the crown of the canine in *Meganthropus* did not differ essentially from that of *Sinanthropus*.

B. FIRST PREMOLAR

The first premolar is a typical bicuspid tooth (Pl. 6, a1, a3, b1, b3), the buccal cusp being more prominent and larger than the lingual. Viewed from the buccal side (Pl. 6, b1), the crown is considerably larger at the occlusal surface than at the neck (9.3 mm. against 6.4 mm.). The buccal surface, as a whole, is asym-

metric, but bulges somewhat more at the mesial side. At both the mesial and distal borders, there is a well-developed cingulum which is more pronounced at the former than at the latter. There is, however, no basal cingulum which unites the mesial and distal ones. Like the buccal surface, the lingual one is asymmetric, its distal half bulging much more than the mesial one. The occlusal surface has two cusps, both located somewhat off the bucco-lingual mid line of the tooth and slightly closer to the mesial border (Pl. 6, a3, b3). The two cusps are not separated by a longitudinal furrow, but the lingual cusp is bordered on either side by very distinct pits, fovea anterior and posterior (Pl. 6, a3, b3). The former is triangular, the latter more quadrangular in shape. The lateral sides of the pits form the edge of the mesial and dis-
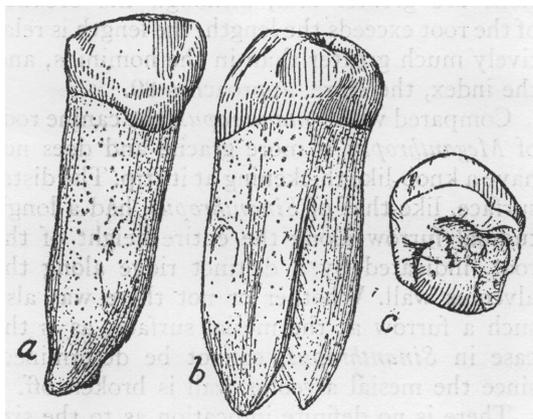

Fig. 9. *Sinanthropus pekinensis*. Right P₁.

tal surfaces. The only discernible wrinkle is small, descending the lingual-distal side of the lingual cusp to the point where the edge of the distal surface forms the lingual border of the fovea posterior.

The form of the crown and the pattern of its buccal and occlusal surfaces are the same as those of the *Sinanthropus* P$_1$.[1] The contour of its occlusal surface exhibits the same asymmetry; the mesial half of the buccal surface and the distal half of the lingual surface both bulge. Furthermore, there is the same arrangement of the cusps as in *Sinanthropus*, the same form and distinctness of the foveae anterior and posterior, and the same development of the cingulum.

[1] Weidenreich, 1937a, Pl. 10, Figs. 80, 82; Pl. 11, Figs. 86, 87; Pl. 34, Fig. 328.

The root of the premolar is exposed on the mesial side for nearly the superior half of its length (Pl. 6, b2, b5). On the exposed side the root is divided into three sections by a shallow anterior furrow and a deeper posterior one. This indicates that there is a larger anterior and a smaller posterior branch of the root. The anterior branch is again composed of two smaller branches, but all three are fused into one piece. Below the neck the root is constricted, but widens as it proceeds downward. X-ray photographs are not available, so neither the length of the root nor the character of its inferior portion can be determined. As in the case of the crown, the conformity of the root with that of the first *Sinanthropus* premolar is obvious. *Sinanthropus* premolar No. 82 (Fig. 9) has the same partition of the root on the mesial side, the same fusion of the three portions, and the same broadening below the neck. As the figures of Table 7 and Diagram b in Fig. 10 indicate, the crown considerably exceeds in size those of all human teeth, fossil or recent. This holds true for all three dimensions, length, breadth, and height. It is of special interest that the teeth of the Heidelberg jaw (Diagram b, Fig. 10), which are considered unusually large, are markedly inferior in size to this new find. The length of the right Heidelberg tooth is 8.1 mm. against 10.0 mm. of *Meganthropus*, and the breadth is 9.0 mm. against 12.0 mm., or, expressed in terms of the rectangles, 73 against 120. The crown of the *Meganthropus* premolar was certainly higher than that of *Sinanthropus*. The worn crown of the former is 9.6 mm. high, while the maximum of *unworn* crowns of *Sinanthropus* premolars is only 9.0 mm. Some of the Krapina teeth and some of those of modern man reach a height of more than 10 mm. The dimensions of the root of the *Meganthropus* tooth, in so far as they can be measured, also exceed those of the *Sinanthropus* first premolar. The greatest breadth is 12.6 mm., while the maximum of the *Sinanthropus* measurements is 9.6 mm. The length is 6.5 mm. (?), the same as the maximum value of *Sinanthropus*.

c. Second Premolar

Like P$_1$, P$_2$ (Pl. 6, a1, a3, b1, b3) is a typical bicuspid tooth with the same characteristics as the former, although the asymmetry of the crown is much more pronounced. This is true not only of the form, but also of the location of

the cusps. In occlusal view (Pl. 6, a3, b3), the distal half of the lingual surface swells considerably in the lingual direction, while the buccal surface rises to a strong, rounded tubercle just above the neck and slightly on the mesial side of the mid line. The cingulum at the latter surface (Pl. 6, b1) is much less developed than in the first premolar; only the mesial portion is discernible and that but faintly. The two cusps seem to be equal in size and height, but this may be the result of attrition. Yet both are plainly located mesial to the transverse mid line of the crown (Pl. 6, a3), so that the talonid portion of the tooth seems to be almost double the size of the trigonid. The anterior and posterior foveae have about the same shape as those of the first premolar, but the anterior is smaller and shallower. Compared with *Sinanthropus*, the *Meganthropus* tooth has the same asymmetric form as that of *Sinanthropus* tooth No. 89.[1] It also agrees in the height and location of the two cusps. But this *Sinanthropus* tooth is not worn and consequently reveals a much more complicated pattern of the buccal and lingual surfaces. In this respect the *Meganthropus* tooth is more nearly like that of *Sinanthropus* tooth No. 93,[2] but this tooth is more worn than the Java specimen. Compared with the second premolar of the *Pithecanthropus* Mandible B, the *Meganthropus* tooth is more symmetrical. Neither the buccal nor the lingual bulge is particularly pronounced, and the talonid is not so much larger than the trigonid. The fissuration of the posterior fovea is much better preserved in the *Pithecanthropus* tooth; it reveals the same general characters as are indicated by the *Meganthropus* specimen which is more worn in this region.

Since only a small portion of the buccal surface of the root is exposed and as no X-ray photograph is available, it cannot be described.

Both length and breadth of the *Meganthropus* tooth are greater than those of *Pithecanthropus* and the maximum values of *Sinanthropus* (cf. Table 7). The rectangle (length ×breadth) amounts to 122 as against 102 and 110 for the two former, respectively. Whether the *Meganthropus* tooth exceeded them in height is uncertain; the *Pithecanthropus* tooth, although worn to about the same degree, is

[1] Weidenreich, 1937a, Pl. 12, Fig. 97o.
[2] Weidenreich, 1937a, Pl. 12, Fig. 98o.

higher, and the maximum height of unworn *Sinanthropus* premolars is greater.

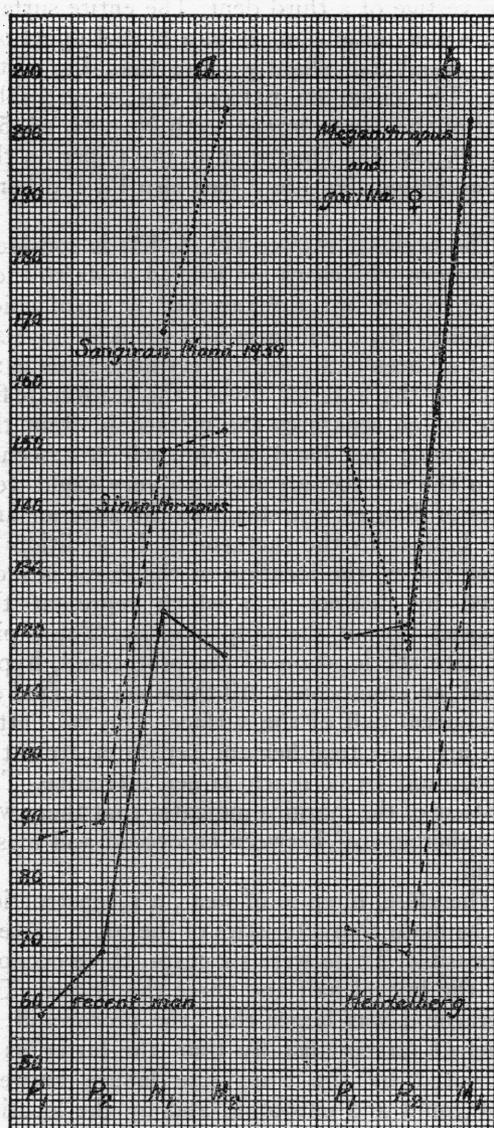
FIG. 10. Millimeter graph showing the size of the lower teeth (P_1, P_2, M_1, M_2) as expressed in the rectangles (length ×breadth) of the crowns.

D. FIRST MOLAR

Pl. 5c; Pl. 6, a1, a2, a3, b1, b2, b3

The buccal surface of the first molar (Pl. 6, b1) has the characteristic traces of a cingulum consisting of a deep, narrow, curved dent, located near the mesial corner. Starting from

the apex of this curve a second shorter dent extends distally parallel to the upper margin of the crown. Near the distal corner of the surface is a vestige of a third dent. The entire surface below the margin bulges in a buccal direction, the mesial half slightly more than the distal one. The cingulum pattern closely resembles that of the *Sinanthropus* teeth Nos. 44, 45, 52, 98, 99, and 137 illustrated in my paper on the *Sinanthropus* dentition[1] (see also Pl. 11d herein).

The occlusal surface (Pl. 6, b3) is considerably worn; the cusps are leveled down to their bases, except for the metaconid, the tip of which is broken off; the fissures and wrinkles have almost all been badly worn. Very little remains: a trace of the anterior fovea; the transverse fissure which separates the metaconid from the entoconid; the distal wrinkle which descends from the metaconid; and two very slight vestiges of fissures, one distal to the anterior and one lingual to the metaconid. In addition to these traces, the location of the cusps is indicated by distinct pits which represent the exposed tips of the pulp cavities. These pits indicate the location of the protoconid, hypoconid, and mesoconid. All three are situated on the buccal half of the surface. The two latter pits are close together and separated from the protoconid by a much larger interstice. The contour of the margins indicates that there was a "tubercle six" between entoconid and mesoconid.

Therefore, in spite of wear, a reconstruction of the main characteristics of the tooth pattern is possible. There were six cusps, three occupying the buccal half and three the lingual. The metaconid was larger than the protoconid. It reached farther distally than the latter, as is indicated by the transverse fissure between metaconid and entoconid and by the location of the hypoconid pit with relation to the protoconid pit. From this arrangement it can be deduced that it had a typical *Dryopithecus* pattern.[2] The surface was covered with wrinkles. In addition to the distal wrinkle of the metaconid, its mesial and middle wrinkles are barely recognizable between the fovea anterior and the rest of the transverse fissure. The form of the occlusal surface, like that of the crown itself, is

oblong, and the length considerably exceeds the breadth (cf. Table 7). The length-breadth index is only 90.3. The trigonid appears slightly broader than the talonid, when the occlusal surface is observed from above, but it is difficult to express this in actual measurements, because the entire buccal surface bulges.

There are anterior and posterior roots (Pl. 5c; Pl. 6, a1, a2, b1, b2). The former descends directly downward, while the latter diverges distally. As far as the exposure of the roots permits examination and measurement, the anterior appears somewhat broader than the posterior (13.2 mm. against 12.7 mm.), while it seems narrower in the mesio-distal direction. In the posterior root, the lower portion of the exposed distal surface exhibits a furrow which indicates a subdivision of the tip into a buccal and a lingual section. The roots of the *Sinanthropus* molars Nos. 102 and 137[3] have the same peculiarities.

Like the two premolars, M_1 of *Meganthropus* is considerably larger than any known human molar, fossil or recent (cf. Table 7). This is particularly true of its length, 15.0 mm. The longest first molar of *Sinanthropus* measures only 13.6 mm.; of the Krapina teeth, the longest first molar is 13.8 mm.; and the length of the first molar in the Heidelberg mandible does not exceed 11.6 mm. The length of the first molar of the *Pithecanthropus* Mandible B is 12.5 mm.

The breadth is less than the length, measuring only 13.5 mm. The maximum breadth of *Sinanthropus* first molars is 12.6 mm., that of *Pithecanthropus* Mandible B is 13.0, of Krapina 12.4, and of Heidelberg 11.2.

The length-breadth index is 90.3 against a minimum index of 91.1 in *Sinanthropus* and 104.0 in *Pithecanthropus* Mandible B. I shall return to this index later.

The measurements of the root (see above) reveal that the breadth of the anterior (13.2 mm.) and posterior (12.0 mm.) branches, like the dimensions of the crown, are greater than the maximum values of *Sinanthropus* (11.0 mm. and 10.4 mm., respectively).

E. Relation between Height and Length of the Two Premolars

In modern man the height of the premolar exceeds the length,[4] that is to say, the height-

[1] Weidenreich, 1937a, Pl. 17, Fig. 140; Pl. 18, Figs. 148, 161; Pl. 19, Fig. 165; Pl. 20, Fig. 177; and Pl. 25, Fig. 339.
[2] Gregory and Hellman, 1926.

[3] Weidenreich, 1937a, Pl. 17, Fig. 141; Pl. 35, Fig. 339.
[4] Weidenreich, 1937a, 103, Diagram 31.

MEASUREMENTS OF THE LOWER TEETH OF *Meganthropus*, THE SANGIRAN MANDIBLE OF 1939, AND ANTHROPOIDS (IN MILLIMETERS)

I. First Premolar (P₁)

Measurement	Meganthropus	Sinanthropus Max.	Min.	Av.	Gorilla ♂ Max.	♂ Min.	♀ Max.	♀ Min.	Chimpanzee ♂ Max.	♂ Min.	♀ Max.	♀ Min.	Orang-utan ♂ Max.	♂ Min.	♀ Max.	♀ Min.
Height	(9.6)	9.6[a]	8.5[a]	8.7[a]	—	—	—	—	—	—	—	—	—	—	—	—
Length (mesio-distal diameter)	10	9.3	7.9	8.65	20.2	14.8	17	13.3	13.4	9.5	12.8	9.4	18	13.4	14.2	10.8
Breadth (bucco-lingual diameter)	12	10.7	8.9	9.9	13	9.2	10.9	8.7	9.1	6.8	8.2	6.3	12.8	8.3	10.5	7
Size of the rectangles (length×breadth)	120	100	70	87	262	136	185	116	125	65	105	59	230	111	149	76

II. Second Premolar (P₂)

Measurement	Meganthropus	Sinanthropus Max.	Min.	Av.	Pithecanthropus Mandible B	Gorilla ♂ Max.	♂ Min.	♀ Max.	♀ Min.	Chimpanzee ♂ Max.	♂ Min.	♀ Max.	♀ Min.	Orang-utan ♂ Max.	♂ Min.	♀ Max.	♀ Min.
Height	(7.6)	8.3[a]	6.5[a]	7.4[a]	(9.3)	—	—	—	—	—	—	—	—	—	—	—	—
Length	10.2	9.9	8.5	9	9.3	12.9	9.9	11.9	9.4	8.8	6.8	8.2	6.2	12.5	9.3	11	8.7
Breadth	12	11.1	8	9.8	10.9	14	10.2	12.9	9.8	9.7	7.3	9.6	6.7	12.9	9.2	11.4	9
Size of the rectangles (length×breadth)	122	110	68	88	101	180	101	153	92	84	50	79	41	161	86	125	78

III. First Molar (M₁)

Measurement	Meganthropus	Sangiran Mandible 1939	Sinanthropus Max.	Min.	Av.	Pithecanthropus Mandible B	Gorilla ♂ Max.	♂ Min.	♀ Max.	♀ Min.	Chimpanzee ♂ Max.	♂ Min.	♀ Max.	♀ Min.	Orang-utan ♂ Max.	♂ Min.	♀ Max.	♀ Min.
Height	(7.2)	(5.0)	8.4[a]	7.2[a]	7.8	7.0	—	—	—	—	—	—	—	—	—	—	—	—
Length	15	13	13.6	11.3	12.6	12.5	17.5	13.1	17.2	13.1	12.3	9.7	11.6	9.1	14.7	12.3	13.3	10.5
Breadth	13.5	13	12.6	11.7	11.8	13	16.2	11.7	15.5	10.9	11.2	8.3	10.5	7.7	14.5	10.8	12.2	9.6
Size of the rectangles	202.5	169	171	125	149	162	283	153	267	143	138	80	122	70	213	133	162	101
Length-breadth index	90.3	100	97.2	91.1	93.7	102	♂ 90.6 / 88.6		♀ 86.7		♂ 88.3 / 87.8		♀ 87.4		♂ 93.4 / 92.5		♀ 91.5	

IV. Second Molar (M₂)

Measurement	Meganthropus	Sangiran Mandible 1939	Sinanthropus Max.	Min.	Av.	Pithecanthropus Mandible B	Gorilla ♂ Max.	♂ Min.	♀ Max.	♀ Min.	Chimpanzee ♂ Max.	♂ Min.	♀ Max.	♀ Min.	Orang-utan ♂ Max.	♂ Min.	♀ Max.	♀ Min.
Height	—	(6)	9.1[a]	6.7[a]	7.6	—	—	—	—	—	—	—	—	—	—	—	—	—
Length	—	14.1	13.2	11.9	12.6	13	19.7	14.6	18.5	14.8	12.9	9.6	12	9.2	16	12.5	13.9	11
Breadth	—	14.3	13.0	11.4	12.6	13	17.3	13.2	16.7	12.4	12.3	9.3	10.8	8.6	15.2	11	13	10.3
Size of the rectangles	—	205	168	136	152	169	341	193	309	187	159	89	130	79	243	137	181	113
Length-breadth index	—	101	100.7	95.9	100	98.5	♂ 89.2 / 88.3		♀ 87.3		♂ 95.5 / 93.6		♀ 91.8		♂ 91.8 / 92.7		♀ 93.6	

[a] Unworn.

length index is below 100, for P_1 84 and for P_2 87.5. In *Sinanthropus* the length is greater than the height, the two indices being 103 and 120, respectively. In *Meganthropus* the two premolars are worn, but when the average height of the worn and unworn teeth of *Sinanthropus* is taken as a base, the probable height of the unworn crown of the *Meganthropus* premolars can be calculated. Since the height of the worn P_1 is 9.6 mm., that of the unworn tooth was about 11.7 mm. In P_2 the corresponding figures are 7.6 and 8.1 mm. Therefore, the height-breadth index of the *Meganthropus* premolars is 117 and 127 against 84 and 87.5 in modern man, and 103 and 120 in *Sinanthropus*.

In anthropoids (unworn teeth) the length of both premolars is usually somewhat greater than the height, but the opposite condition also occurs.

In the first molar the height-length index was certainly more than 171 (*Sinanthropus*) compared with 138 in modern man.

C. THE RECONSTRUCTION OF THE *MEGANTHROPUS* MANDIBLE

The reconstruction of the mandible (Pl. 7a, 8a) has been carried out only so far as the fragment offers direct clues to the form and character of the missing parts. In mesial direction, the right half of the jaw could, without any difficulty, be completed up to the symphysis; and even beyond the mid line the configuration and extent of the outer and inner surfaces of the front part are sufficiently indicated by the preserved basal portions and the location of the alveolus of the canine. It was also possible to complete the body of the mandible in a distal direction as far as the posterior half of the second molar. The left half of the jaw was modeled to conform symmetrically with the right half. The curvature of the front part was indicated by the preserved portion on the right side. This extends mesially to the chin and on the lingual side just beyond the area of the fossa genioglossi and the mental spine, that is to say, somewhat beyond the mid line. Although neither the incisors nor the canines are preserved, the size of the alveolus of the right canine reveals that this tooth was no larger than the *Sinanthropus* canine and, basically, of the same form. Therefore, it is safe to assume a similar resemblance in the form of the medial and lateral incisors. Thus the canine and incisors of *Sinanthropus* could serve as models for the reconstruction of the front teeth.

In order to suggest the form of the dental arch, it seemed best to prolong the posterior parts of the body behind the third molar to the ascent of the ramus. To reconstruct the second and third molars, the corresponding teeth of the *Pithecanthropus* Mandible B were used as models, proportionately enlarged to the size of the preserved first molar of *Meganthropus*.

Although some details remain doubtful, the reconstruction of the mandible as a whole, particularly those parts which it was possible to restore with a high degree of accuracy, gives a very fair idea of its size, general form, and proportions. It also effectively illustrates the characteristic features of the fragment.

In modeling the reconstruction I had the benefit of the skilful help of Mr. Otto Falkenbach of the Laboratory of Paleontology.

1. GENERAL ASPECT

The most conspicuous feature of the mandible, regardless of the angle from which it is viewed, is its great size, massiveness, and clumsiness. In mandibles of the large anthropoids, particularly in male gorillas and orangs, the anterior lateral region of the body is slender and rather gracile. This is due to the deep compression of the alveolar process, beginning immediately posterior to the alveolar jugum of the canine and extending backward to the second molar, while there is no similar reduction recognizable in *Meganthropus*. The impression of clumsiness is intensified by the relative shortness of the entire body of the jaw; the breadth of the mandible at the level of the second molar amounts to 99 mm. and in the line of the first premolar to 67 mm., against a length of 85 mm., measured from the most prominent point of the frontal surface to a vertical plane erected through the posterior ends of the third molars. The breadth-length index of the body is, there-

fore, 117 in the molar region and 78.8 in the region of the first premolar. So we see that the breadth exceeds the length considerably in the molar region, while the length exceeds the breadth in the premolar region. In the male gorilla the breadth is less than the length in the molar region but in the male orang-utan it may exceed the length while, in both instances, the conditions of the premolar region are the same as in *Meganthropus*.

That the breadth measurements so greatly exceed those of length in *Meganthropus* is not due to extraordinary breadth, but to a considerable reduction in the length. This is because the front of the mandible is nearly vertical (Pl. 8, a2). In other words, the alveolar process which contains the incisors does not protrude far beyond the base, as is usual in anthropoids, but holds to the same frontal plane. There is, therefore, almost no "prognathism," nor is there any mental prominence at the basal part of the front.

2. SPECIAL FEATURES

A. INCISURA SUBMENTALIS

When the mandible is placed on an even plane the symphyseal portion remains high above the base (Pl. 7, a2). The body touches the plane only at the vertical level of the first premolar. The upward curve of the symphyseal section of the lower margin between these two points of contact represents the so-called incisura submentalis, first described in the Heidelberg jaw (Pl. 7, b2). It is impossible to determine the exact height of this notch, for the base of the ramus, on which the correct orientation depends, is not preserved. However, the form of the basal bulge on which the fragment rests makes it certain that the jaw was a "rocking" mandible, a type which is of common occurrence in modern man and not rare in the anthropoids. The statement I made in the description of the *Sinanthropus* jaw[1] that, "not the incisura submentalis but the downward projection of the two halves of the body constitutes the essential characteristic of the outline," is proved correct by the pronounced development of the notch, which corresponds to the enormous bulging of the lower margin.

[1] Weidenreich, 1936.

B. RECESSUS DIGASTRICUS

Of far greater morphological significance is another indentation which is partly niched in the notch. This peculiarity has never been observed before in any hominid or anthropoid mandible. Lacking a better name I propose to call it the "recessus digastricus." I have already referred to this feature in the description of the lower margin of the fragment, but the reconstruction of the missing side presents the real picture of this formation. When the mandible is observed from below there is a distinct niche below the symphyseal vertex of the basal arch (rd, Pl. 7, a4). The entrance to this recess is marked on either side by the knob-like swelling of the lower margin, which I called tuberculum fossae digastricae (tfd, see p. 39). When viewed from behind (Pl. 8, a1), the recess appears as a special high and narrow niche located precisely at the base of the symphysis. This niche has a width of 19 mm. measured at its base; its height is about 15 mm. Its lateral wall is identical with the triangular depression which I have described above as equivalent to the digastric fossa of the hominids (fd, Pl. 6, b2; Pl. 8, a1, a2). The roof of the niche is formed by the symphysis or, more correctly, the under side of the "Basalplatte" (torus transversus inferior). A median section through the symphysis (see the following paragraph) will show the exact position of the roof (Pl. 8, a2). A slight median crest supposedly continued the unpaired lower portion of the mental spine described above. This is indicated by a division of the recess into a right and left half.

The digastric recessus is an anomaly and has no analogy either in the known hominids or in the living anthropoids. As the illustrations show, it is not identical with the incisura submentalis, but occupies only the lingual side of the vertex of this notch. As was shown above, the incisura submentalis is formed by the upward bend of the entire lower margin and involves, therefore, the whole frontal region of the mandible, whereas the recessus is a special differentiation of the median lingual area. The incisura is visible only if the mandible is viewed from the front (Pl. 7, a2), the recessus, however, only when observed from behind (Pl. 8, a1). In the *Sinanthropus* Mandible H I and in the Heidelberg mandible, in both of which the region in question is best preserved and very distinctly developed, the digastric fossa oc-

cupies the entire lower surface of the mandible (Pl. 7, b4) from the mid line back to the level of the second premolar. The contour of the lower margin of the mandible bulges downward in both cases (incisura submentalis) and reaches its lowest point at the level of the second premolar in *Sinanthropus* and *Pithecanthropus* (Mandible B) and at that of the first molar in the Heidelberg jaw (Pl. 7, b1, b2). In both cases this point is marked by a rough elevated area which occupies the buccal rather than the lower surface of the bulge. I have designated the elevated area as "tuberculum marginale anterius" (cf. tma, Fig. 8a, b) and the entire bulge as "torus marginalis."[1] If we identify both these features with those of the *Meganthropus* mandible there is only one possible conclusion: the "torus marginalis" is not differentiated but is merged, as it were, into the bulge of the body in the region of the mental foramen. Then the "tuberculum marginale anterius" corresponds to the knob which marks the entrance to the digastric recessus (tfd, Pl. 6, b2) on the border between the lingual surface and the lower margin of the mandible. These interpretations seem justified by the appearance of the digastric fossa. In the two hominid mandibles, referred to above, the tuberculum is situated near the posterior end of the digastric fossa which occupies the entire inferior surface. In the *Meganthropus* mandible the knob marks the apex of a triangular area which can be interpreted only as the equivalent of the digastric fossa. In the anthropoids, on the other hand, there is neither a distinct torus marginalis nor a tuberculum marginale.

The digastric recess of the *Meganthropus* mandible has, therefore, no parallel either in hominids or in living anthropoids. In hominids the vertex of the basal arch is a very wide curve, while in the anthropoids it is very narrow. In neither is the vertex portion separated from the rest of the arch. The digastric muscle occupies an area, either smaller or larger, flat or depressed, on the lower surface which is separated from the rest by a line or crest. In only one small orang-utan in the collections of the American Museum of Natural History (C.A. No. 1811) did I find conditions which resemble, to a small degree, those characteristic of the

Meganthropus mandible. In this specimen the vertex of the basal curve divides into two lines, an outer and an inner, which enclose a space consisting of two triangular areas separated from each other by an irregular median crest. This vertex differentiation is not a real recessus but corresponds to it by its location on the under side of the "Basalplatte" (torus transversus inferior). It is surprising that the only feature which has some resemblance to that of *Meganthropus* is found in an orang-utan. According to the literature, the anterior belly of the digastric muscle, which is inserted at the area in question, is lacking in orang-utan. However, Toldt[2] who devoted special study to the digastricus of the orang-utan believes that the anterior belly was developed in this anthropoid and that, in certain cases, bundles may reappear and fuse with the under side of the mylohyoideus, thus showing a certain degree of individuality. In those cases a typical fossa digastrica may also be present in orang-utan. In fossil anthropoids, the front of the lower jaw with the vertex of the basal arch and the digastric region are in no case preserved. In *Dryopithecus pilgrimi*, however, the left half of the mandible is preserved with the break to the right of the symphysis.[3] The symphyseal region has the characteristic pattern of the anthropoids, but there is a distinct under side to the "Basalplatte" which exhibits a triangular area already recognized by Smith Woodward (fd, Pl. 8c). The two fossae are separated from each other by a distinct crest. The digastric area does not have the appearance of a recessus, because the tubercle, which marks its entrance in *Meganthropus*, is not developed; but the whole region resembles the condition of that in *Meganthropus* much more than that in any of the living anthropoids (Pl. 8, a2 and Pl. 8c). In *Dryopithecus fontani* (Lérida) the left half of the mandible, with the symphyseal region, is preserved. In this case there is also a triangular area below the "Basalplatte" at the lingual side of the symphysis. It is similar in form to the digastric triangle of *Meganthropus*, but differs in its location. As in the case of the orang-utan described above there is no trace of a special tubercle which separates the vertex of the basal arch from the rest of the curve.

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[1] Weidenreich, 1936.

[2] Toldt, 1907.
[3] Smith Woodward, 1914.

FIG. 11. Alveolar and basal arches of the *Meganthropus* mandible compared with those of a female gorilla (a), *Sinanthropus* Mandible G I (b), Heidelberg mandible (c), and male Australian aborigine (d).

c. ALVEOLAR AND BASAL ARCHES

When the fragment of the mandible is viewed from the occlusal side (Pl. 6, a3, b3), the first impression is that the three teeth *in situ* (P_1–M_1) are arranged in a straight line which forms a distinct angle with the direction of the front section of the alveolar arch, which is not itself preserved, but is suggested by the shape

of its preserved basal portion. In other words, it seems that the alveolar and dental arches made a sharp bend at the canine, so that the teeth distal to it ran straight backward, while those mesial to the canine were arranged in a moderate frontal curve. The formation of an angle at the point where the front section of the alveolar arch continued into the side rows of

the teeth is a typical simian feature (Fig. 11a). In man and all known hominids the alveolar arch has a form rather like that of a horseshoe, that is to say, the front section curves gradually into the side rows which themselves are curved (Fig. 11d). The canine does not mark an angle where two divergent lines join, but is aligned with the front teeth so that the curve is continuous.

Gregory and Hellman, in their classification of the dental arches of the anthropoids and man,[1] distinguished five classes, chiefly based on the arrangement and direction of the side rows. The hominids are assigned to Class V and the anthropoids to Classes I to IV and Class V, according to these authors. Class V is characterized by an arch "posteriorly divergent" with "sides straight, or nearly so," the arch being "parabolic." I consider the formation of the angle and the straightening of the side rows as typical features of the anthropoid arch, and the differences in the special form of the side rows as of minor importance. The development of an angle in the dental arch is, of course, dependent on the size of the canine. The larger the tooth, the more it projects and the more pronounced are the curves of the alveolar and dental arches. The small canines of the hominids do not project and, therefore, the arch forms a continuous curve. *Meganthropus*, with a small canine, follows the human line in this regard. On the other hand, the side rows of *Meganthropus* were both straight and divergent. As straightness is a simian feature and divergence a hominid one, at least when man is compared with modern anthropoids, *Meganthropus* combines the characteristics of both groups.
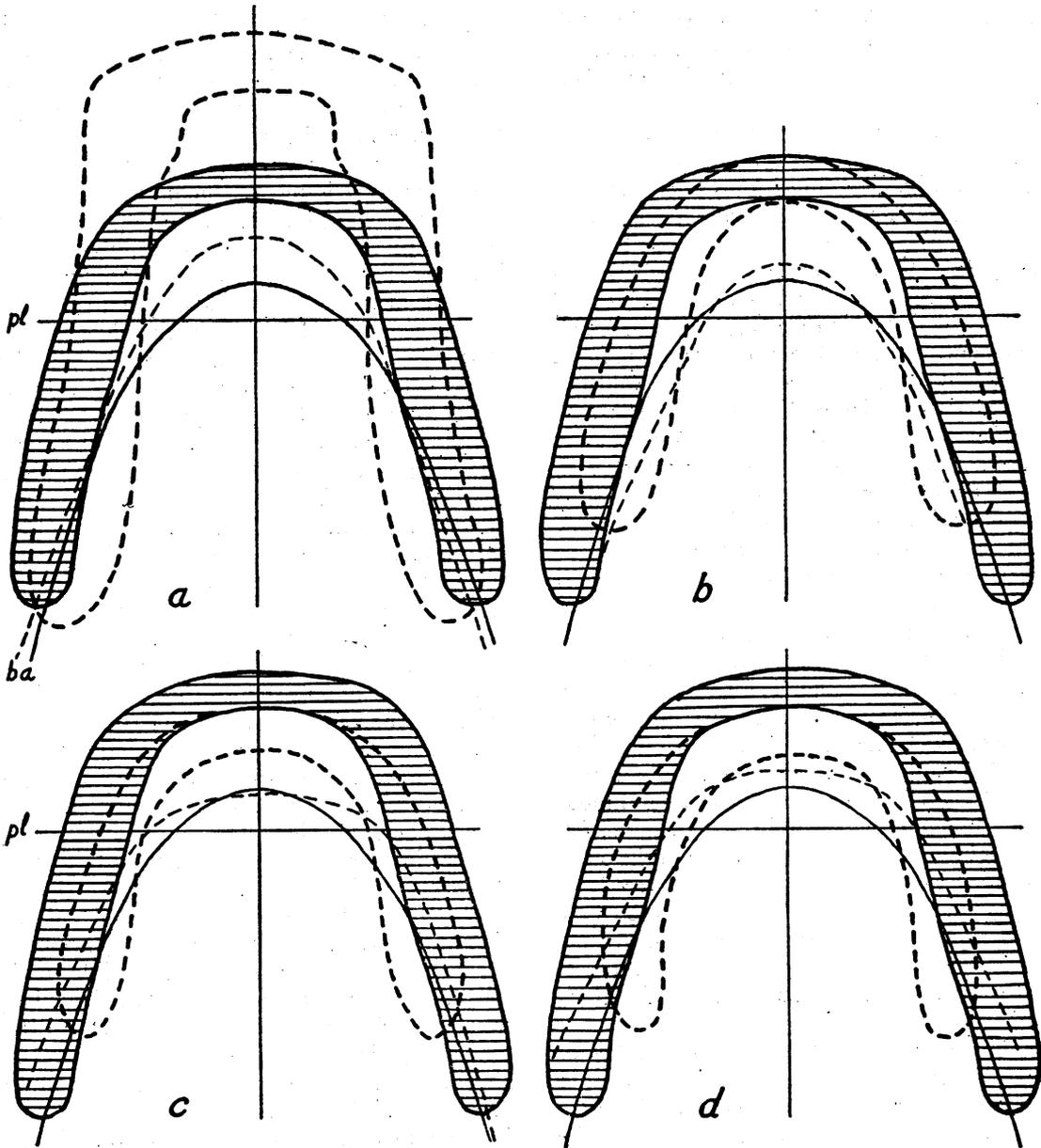
In Fig. 11 the alveolar and basal arches of *Meganthropus* are compared with those of a female gorilla (a), the *Sinanthropus* Mandible G I (b), the Heidelberg mandible (c), and the mandible of a male Australian aborigine (d). The alveolar arch of *Meganthropus* is shaded in each case. The arches used in comparison are superimposed on it on the mid line and on a transverse line which corresponds to Bolk's[2] "postlacteon" line drawn through the interstices between P_2 and M_1. The alveolar arch of *Meganthropus*, compared with that of a gorilla (a), reveals the *Meganthropus* arch to be considerably shorter than the latter. The greater

length of the gorilla arch lies almost completely in the anterior ("lacteal") portion of the arch (portion in front of the postlacteon line), while the side row behind the postlacteon is only a trifle longer. In other words, the prolongation is due to the greater length of the canine and first premolar; that is to say, the gorilla belongs to the "heteromorphic canine group," *Meganthropus* to the "homomorphic canine group."[3] The fact that in the gorilla the canine itself is a member of the side row adds, of course, to the greater length of the gorilla arch, while the fact that it has "moved around the corner" and become a member of the front row in *Meganthropus* naturally shortens the arch of the latter. On the other hand, the lacteal arch is narrower and the postlacteal arch wider in *Meganthropus* than in gorilla. The greater narrowness of the lacteal arch is in accordance with the small size of the canines, while the greater width of the postlacteal arch is due to the divergence of the side rows. The straightness of the side rows has little or no relation to their divergence. The side rows may be straight or curved inward or outward (as happens in anthropoids) without affecting the general direction of the rows.

In common with *Meganthropus*, all hominids (Fig. 11b, c, d) have the short lacteal arch and the divergence of the side rows, but their alveolar arches, on the whole, are considerably smaller in longitudinal as well as in transverse direction. It is of particular interest that in *Sinanthropus* (b) the length of the lacteal portion of the arch is the same as in *Meganthropus*, in spite of its general shortening, while in the Neanderthalians, represented by the Heidelberg mandible (c) and likewise in recent man (d) the lacteal portion has also contributed to the shortening. Furthermore, the side rows are almost as straight in *Sinanthropus* (b) as they are in *Meganthropus*, while their inward curve, characteristic of modern man (d), is already evident in the Heidelberg jaw (c).

If the differences in size and form of the alveolar arch (illustrated by the diagrams in Fig. 11) are expressed in figures (Table 8), the total length of the *Meganthropus* arch is about three quarters that of the female gorilla, while it is about one third greater than that of the Heidelberg jaw and modern man. The greatest breadth of *Meganthropus* is about one tenth more than that of the female gorilla and from

[1] Gregory and Hellman, 1939a.

[2] Bolk, 1926b.

[3] Weidenreich, 1936 and 1943b.

one fifth to one fourth more than that of the Heidelberg jaw and modern man. The length of the lacteal arch of *Meganthropus* is about one third of the total length of the arch compared with about one half in gorilla. In fossil hominids and modern man it is only about one fourth. The relative total length and breadth of the alveolar arch of *Meganthropus*, with an index of 112 (Table 8), falls entirely within the range of the hominids and far beyond that of the gorilla. This is in full accord with the shortness of the mandible, the length of which is less than the greatest breadth, while in the gorilla the reverse is true (index 79).

is, obviously, narrower and thus approximates the condition of the gorilla.

D. MID-SAGITTAL SECTION THROUGH THE SYMPHYSIS

The mid-sagittal section through the symphysis of the reconstructed mandible provides a good picture of its form and thickness and also permits certain fairly exact measurements to be taken. Since the greater part of this region is preserved and only the smaller upper portion is restored, as indicated in the illustrations (Pl. 8, a2; Fig. 12), this section can be considered as a valid basis for comparison, and the angle of

TABLE 8

MEASUREMENTS OF THE ALVEOLAR ARCH OF THE *Meganthropus* MANDIBLE COMPARED WITH GORILLA AND HOMINIDS, AS ILLUSTRATED IN FIG. 11 (IN MILLIMETERS)

No.	Measurements	*Meganthropus*	*Sinanthropus* G I	Heidelberg	Recent Man (Australian)	Gorilla
1	Total length of the alveolar arch	77	65	57	56.5	103
2	Length of the anterior portion	27.5	28	21	21	50
3	Length index of the anterior portion	35.7	23.2	27.1	26.9	48.7
4	Greatest breadth of the alveolar arch	86	72	70	65	79
5	Breadth of the anterior portion	68	60	57	57	64
6	Length-breadth index of the total arch	112	111	120.5	115	76.7

The basal arch is represented in the diagrams of Fig. 11 by broken and unbroken lines forming parabolic curves, which correspond to impressions left by the lower margins of the various mandibles when they were pressed on an even surface after inking the under surface. These lines form the arch of the basal portion of the body. The longitudinal axis is shorter than that of the alveolar arch in proportion to the degree of projection of the alveolar process or, in other words, the greater the prognathism. The distance that the incision projects beyond the vertex of the basal arch indicates how far the alveolar process juts out beyond its base, a distance which can be measured. The parabola of the basal arch is narrow in the gorilla (a), while it is wide in recent man (d). This is in full accord with the general form of the mandible and the alveolar arch. The only difference between *Meganthropus* and gorilla is that the lacteal portion of the former is a good deal shorter, while the width is virtually the same in both. Compared with Heidelberg (c) and recent man (d), however, the basal arch of *Meganthropus* has about the same length, but

inclination to the alveolar plane can be directly measured.

The *Meganthropus* diagram shows that the thickness of the symphysis far exceeds that of any recent or fossil anthropoid or hominid. The angle of inclination of the incision-gnathion line (Fig. 12, i–gn) to the alveolar-plane (Fig. 12, i–b, etc.) totals 58° (Table 9). This is greater than that of the recent anthropoids which varies from 44° to 50° in the cases illustrated, but is smaller than that of recent man which is from 75° to 91° in the cases figured. In other words, the symphysis of the *Meganthropus* mandible is more erect than in anthropoids, but more inclined than in man. Compared with fossil hominids with angles of from 60° to 64°, the inclination of *Meganthropus* is greater and the angle closer to that of the recent anthropoids. As for the fossil anthropoids, *Meganthropus* has about the same inclination angle as *Dryopithecus fontani* (59°), and also has in common with this specimen the location and form of the digastric fossa (see p. 46). Other types of the *Dryopithecus* group (except *Ramapithecus*) do not differ essentially from recent anthropoids.
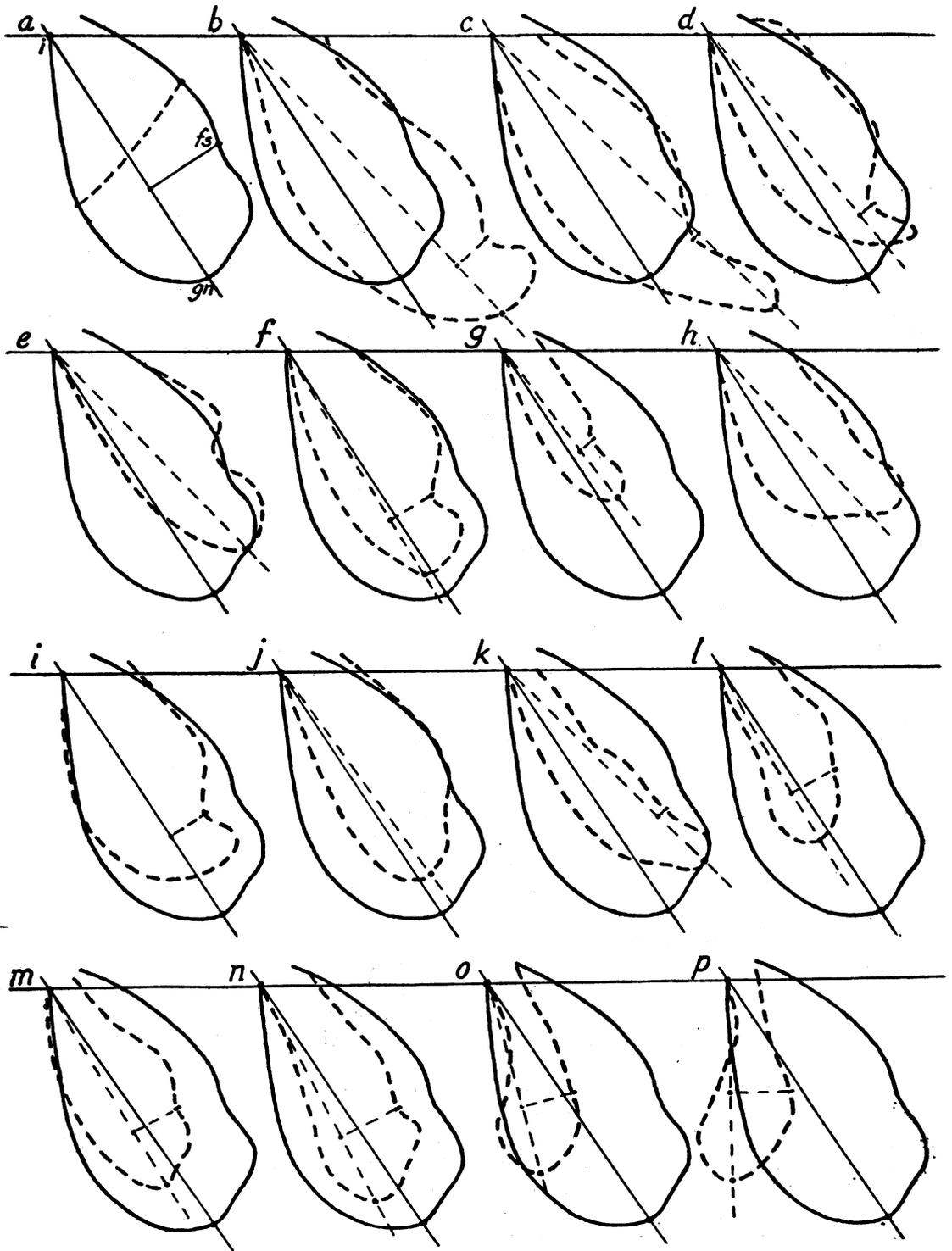
FIG. 12. Mid-sagittal sections through the symphysis of the *Meganthropus* mandible (a) compared with anthropoids, recent (b–d) and fossil (e–j), and hominids, recent (o, p) and fossil (k–n).

The form shown by the *Meganthropus* diagram is surprisingly similar to that of fossil hominids as represented in Fig. 12 by the Heidelberg mandible (m) and the Krapina mandible H (n). The formation of the basal portion of the symphysis is the most characteristic peculiarity, making it possible to distinguish typical hominids from typical anthropoids at first glance. Below the fossa genioglossi, indicated in the diagrams by a more or less pronounced

approach to the human line in this pattern; the diagram which is drawn from McGregor's reconstruction[1] resembles a reduced copy of the diagram of the male orang-utan (c).

Meganthropus also reveals its hominid character in the position of the foramen supraspinosum. As was previously stated, this foramen marks the approximate limit between the alveolar process and the basal portion of the body of the mandible. In the anthropoids,

TABLE 9

MEASUREMENTS TAKEN ON MID-SAGITTAL SECTIONS THROUGH THE SYMPHYSIS OF *Meganthropus*, ANTHROPOIDS, AND HOMINIDS (CF. FIG. 12)

Specimen	Distance: incision-gnathion (in mm.)	Incision—base of foramen supraspinosum (in mm.)	Index of the position of the foramen supraspinosum	Angle of inclination
a. *Meganthropus*	47	29.5	62.8	58°
b. Gorilla ♂	62.5	51.5	82.4	47°
c. Orang-utan ♂	64.5	47	72.8	44°
d. Chimpanzee ♂	44	39	88.7	50°
e. *Dryopithecus pilgrimi*	45	36.5	81.2	46°
f. *Dryopithecus fontani*	43	32	74.4	59°
g. *Ramapithecus brevirostris*	31	21	67.8	57°
h. *Sivapithecus himalayensis*	36	—	—	47°
i. *Paranthropus robustus*	39	32?	82.1?	58°
j. Sangiran Mandible of 1939	40	—	—	54°
k. Piltdown reconstruction after McGregor	45	34.5	76.7?	45°
l. *Sinanthropus* H I	32.5	23	70.8	(60.5°) 63°
m. Heidelberg	37.5	27.5	73.3	(60.5°) 63°
n. Krapina H	40	28	70.1	63.5°
o. Recent Australian	33	21.5	65.2	75.0°
p. Modern Late Palaeolithic man (upper cave of Choukoutien)	33	18.5	56.2	91°

nounced incurve of the lingual contour, the symphysis shows a beak-like, backward projection (Fig. 12b–d) which is absent in all hominids. In fossil types, however, the base not only seems to be clearly cut off (Fig. 12m, n), but even appears to be pushed forward. This is a trend which is responsible for the development of the chin of modern man where almost the entire front portion projects in a forward direction (Fig. 12n–p). *Meganthropus* is, therefore, undoubtedly hominid (m). Of the fossil anthropoids, *Dryopithecus fontani* (f) is, again, the closest, while *Sivapithecus himalayensis* (h) exhibits the anthropoid pattern. The same is true of *Paranthropus robustus* (i), although in this case the basal beak is not so pronounced as in recent anthropoids. It is interesting to note that the Piltdown mandible (k) does not show any

where the former is higher and larger than the latter, the foramen is located nearer the base. In modern man, where conditions are reversed, it is located much higher up. A precise calculation of its position can be made by means of the mid-sagittal diagram. The base of a vertical drawn from the foramen (fs, Fig. 12a) to the incision-gnathion (i-gn) line divides this line into an upper and a lower section. The length of the upper section in percentage of the total length of the line—index of the position of the foramen (Table 9)—indicates which section is longer. If the index is over 50, the foramen is nearer the base and the alveolar process is larger than the basal portion of the body. If the index is below 50, the alveolar process is smaller

[1] McGregor, 1916.

and the basal portion relatively larger. In *Meganthropus* the index is 62.8 (Table 9); in recent man the listed indices are 56.2 and 65.2, while those recorded for anthropoids vary from 72.8 to 88.7. *Meganthropus* falls, therefore, within the hominid range.

D. ANALYSIS OF THE CHARACTER OF THE *MEGANTHROPUS* MANDIBLE

All the facts reported above indicate that the *Meganthropus* mandible is that of a hominid. Hominid characters are: 1, the configuration of the symphyseal portion; 2, the development of a mental spine; 3, the high position of the foramen supraspinosum; 4, the position of the digastric fossa; 5, the high position of the mental foramen; 6, the homomorphic character of the canine group, i.e., small canine, bicuspidate first premolar; and 7, the form of the alveolar arch, i.e., moderate prognathism and gradual continuation of the frontal curve into the side rows which are divergent.

But some of these hominid characters are of a more primitive nature than those found in *Sinanthropus* and *Pithecanthropus* Mandible B: 1, the mental spine (Pl. 5c) is in the first stage of development and, therefore, less pronounced than in *Sinanthropus;* 2, the foramen supraspinosum (Pl. 5c) consists of two relatively large foramina which are located behind a distinct pit (fossa genioglossi); 3, there is no indication of the chin—tuber symphyseos—(Pl. 7, a1; Pl. 8, a2); 4, the digastric fossa (Pl. 8, a1) is placed at the lingual surface of a special recessus which recalls the condition of *Dryopithecus fontani;* and 5, the side rows of the alveolar arch form straight lines, in spite of their divergence (Pl. 7, a3).

There are certain characters, not so far encountered in any hominid, which must also be noted. These are: 1, the enormous size of bone and teeth; 2, the bulging of the buccal and lower surfaces; and 3, the formation of a distinct digastric recessus (Pl. 7, a4; Pl. 8, a1). The mandible cannot be attributed to a type of the size of *Pithecanthropus robustus*, for both bone and teeth are larger than can be expected with any degree of reasonableness for any mandible of *Pithecanthropus robustus*.

One question still remains for discussion. Some scientists to whom I showed the cast were so impressed by the extraordinary size of the mandible that they have raised the question, or at least the possibility, that the bone might not be a normal one, but might have been affected by some pathologic process such as acromegaly or some similar disease. The most characteristic feature of acromegaly is a true hypertrophy of the terminal parts of the body, particularly the face and extremities. As the mandible represents the terminal part of the face, it is the skeletal part most often subject to overgrowth. But the hypertrophy caused by acromegaly is quite a special kind. In all the cases of acromegaly described,[1] the overgrowth of the mandible consists chiefly in an elongation of the ramus and the body with an increased condylion-gonion-gnathion length. As a result of this growth in terminal direction, the mandibular angle widens increasingly and the chin becomes extremely prominent (Fig. 13a, b). Corresponding to this increase in length, or more properly in depth, the body, particularly the symphyseal region, increases in height. Since the hypertrophy involves mainly the basal portion of the mandible, the alveolar process is much less affected. The former becomes thicker and the lower margin more rounded, while the alveolar process not only retains the primary conditions, but in some cases appears even more gracile. These differences in growth produce a peculiar effect; the entire basal portion, including the chin region, protrudes and seems demarcated from the alveolar process by a sulcus-like "incurvatio" along the entire circumference of the body. As acromegaly is a disturbance which sets in toward the end of normal growth, the teeth, which have attained their form and full growth before this period, retain their normal size in all cases.

Although the ramus of the *Meganthropus* mandible is not preserved and only the body is available, it can be stated with certainty that this mandible does not owe its enormous size to an acromegalic process. Not only has the entire basal portion undergone enlargement, but the alveolar process and even the teeth have also partaken of this growth. There is, in particular, no indication of a peculiar prominence

[1] Thomson, 1890; Cunningham, 1890; Fawcett, 1904; Geddes, 1911; Seer, 1925.

of the chin region (Fig. 13; Pl. 6, a2, b2; Pl. 7, a1; Pl. 8, a2). On the contrary, there is no chin, and the angle of inclination, which is over 100° in acromegalic mandibles, is smaller in *Megan-thropus* than that of normal human mandibles and even smaller than that of any fossil mandible (Table 9).

But another possibility remains. Some of the *Sinanthropus* mandibles have a large protuberance on the lingual surface, the so-called torus mandibularis. This protuberance is characterized by two peculiarities: 1, it is restricted to

trace of enlargement. On the contrary, the remaining anterior teeth show a marked shortening of their roots and a corresponding shallowness of their sockets, caused by the upward expansion of the protuberance. The character of this deformity can be gathered from a cross-section through the socket of the posterior root of the second molars, originally given by the authors and reproduced in Fig. 16b. The illustration reveals that, contrary to normal conditions (Fig. 16c), the outer and inner tables have been attenuated and replaced by a dense can-
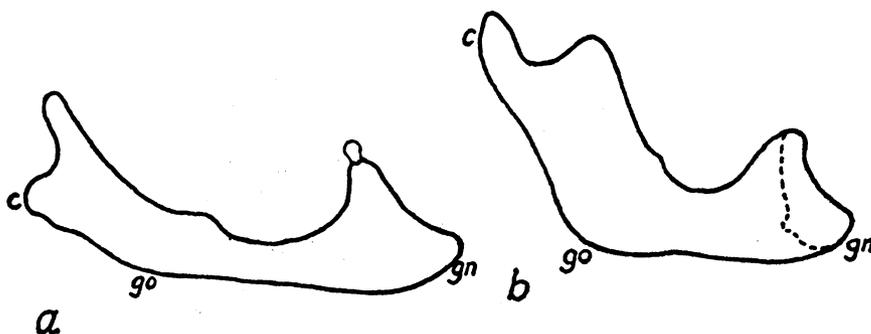

FIG. 13. Acromegalic human mandibles.

the alveolar portion between canine and second molar; and 2, it is exclusively a hypertrophy of the inner table, the structure of which resembles that of ivory.[1] Although it is clear that the peculiarities of the *Meganthropus* mandible cannot be interpreted as a kind of torus mandibularis, a similar hypertrophic process could have affected other and larger parts of the mandible as in the case of the torus. However, all we know of these exostoses or protuberances indicates that they never involve the entire bone but are confined to specific areas, either smaller or larger, and never affect the teeth. The only case reported in the literature (as far as I was able to discover), where almost the entire body of the mandible was affected, was the mandible of a recent Melanesian (New Guinea) skull described by Gullberg and Burkitt.[2] In this case the hypertrophic process mainly affected the basal portion of the body in the premolar and molar region of the left side and that of the right side to a slighter degree (Figs. 14 and 15). The alveolar portion and the symphyseal region are much less affected; the rami and teeth show no

cellous structure. Whether the hypertrophy is to be considered as a circumscribed "leontiasis ossea" or a localized Paget's disease, an interpretation which the authors reject, is of little importance. What is significant is the fact that the abnormal shape of the Melanesian jaw is not comparable with the condition of the *Megan-thropus* mandible. In the latter there is no partial hypertrophy of the body; all its parts, including the teeth, have contributed to the enlargement. Unfortunately, the *Meganthropus* cast cannot give any clue to the internal structure of the bone, although it is exposed by fracture at exactly the same level as that shown in the cross-section through the hypertrophied Melanesian mandible (Fig. 16b). Nevertheless, one decisive difference is revealed. In the hypertrophic mandible (Fig. 16b), the abnormal growth affects chiefly the basal portion and causes its expansion in lingual and downward direction; the mandibular canal is "eccentric," as it were, when compared with its normal location within the diploë. In *Meganthropus* (Pl. 5c; Fig. 16a), however, the mandibular canal has the same relative position as under normal conditions, such as it should have if the enlarge-

[1] Weidenreich, 1936.
[2] Gullberg and Burkitt, 1925.

ment were a general one and not caused by circumscribed pathologic alterations. The cross-sections shown in Fig. 16 also demonstrate the differences in the sockets of the molar roots. The socket of the Melanesian jaw (Fig. 16b) is about the same size as that of the European (Fig. 16c), but that of the *Meganthropus* jaw (Fig. 16a)—the tooth itself is shown instead of
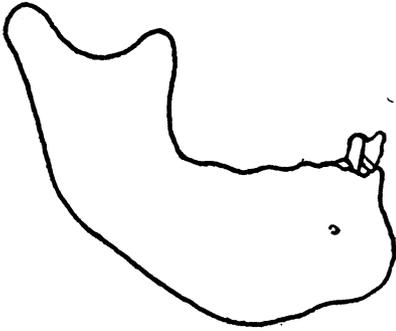

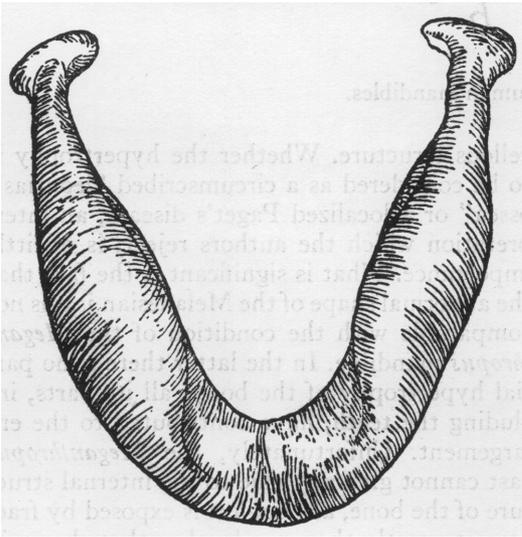FIG. 14. Deformed mandible of a Melanesian.

FIG. 15. Deformed mandible of a Melanesian, viewed from below.

the socket—is much larger than the Melanesian jaw, a condition in full conformity with the enlargement of the jaw in its entirety.

In rare cases, a localized hyperostosis may appear as a seemingly normal structure which marks the only difference from other, similar forms. It may even seem a specific differentiation of a particular type. This has occurred, for instance, in the lower jaw of a deer which is characteristic of the Choukoutien fauna. C. C.

Young[1] called this form, first described by Zdansky,[2] *Cervus (Euryceros) pachyosteus*. According to Young, the chief characteristic of the mandible is an extreme hyperostosis which curiously modified both ramus and body.

The body is so swollen as to become more or less circular in transverse section. . . . The thickening . . . is most conspicuous under the molars. . . . A noticeable fact is the broad range of variation both in thickness and in the size. . . . Sometimes the part near the molars is sharply projecting; sometimes it swells so gently as to look almost flat. Sometimes the thickness is observed on both sides; sometimes only on the outer (or more rarely on the inner) side of the jaw.[3]

According to Zdansky[4] the hypertrophic parts of the mandible are formed by a mass of compact bony substance which surrounds an abnormally narrow mandibular canal. Furthermore, it is interesting to note that: 1, the pachyostosis is not restricted to the lower jaw, but affects the other parts of the skull although to a much smaller extent; 2, neither the teeth nor the other skeletal bones show any essential deviation from the non-pachyostic type of deer.

This is not the place to enter into a discussion of the nature of this abnormality, or of the justification for distinguishing a pachyostotic deer as specifically different from an otherwise similar form. Nor is either of these points the one which, just now at least, demands our attention. The point is the hyperostosis itself. In the deer the hyperostosis consists of a kind of eburnation of the whole affected bone which leaves only a restricted space for the mandibular canal. This condition surprisingly resembles the structural peculiarity of the mandibular torus of *Sinanthropus*. As the hypertrophy of the Melanesian mandible described above consists only of spongy substance, it apparently belongs to quite a different category of bone alterations.

In any case, from the preceding considerations it seems clear that the enormous size of the *Meganthropus* mandible cannot be due to any deformations such as have been described. It is certainly not the result of a circumscribed pathologic process, for it comprises, in correct proportions, all the essential constituents of the

[1] Young, 1932a.
[2] Zdansky, 1925.
[3] Young, 1932b.
[4] Zdansky, 1925, 1928.
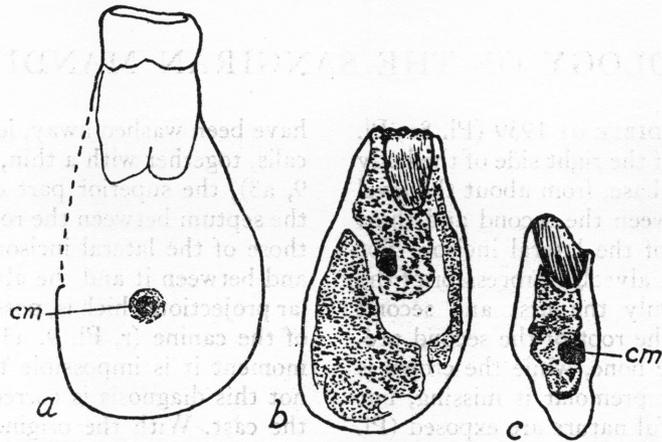
Fig. 16. Cross-sections through the mandibles of *Meganthropus* (a), the Melanesian of Figs. 14 and 15 (b), and a normal European (c).

mandible, basal and alveolar portions, with their internal structures, including the teeth. The mandible represents, therefore, not a purely accidental malformation, but the "normal" bone of a genuine giant form of early man.

For all these reasons I agree with Dr. von Koenigswald in separating this new Sangiran mandible morphologically from *Pithecanthropus* and in applying a special name to it. *Meganthropus palaeojavanicus* is certainly a suitable name, although *Megalanthropus* may be etymologically more correct. In accepting von Koenigswald's classification I want, however, to state that this acceptance excludes certain points. I do not acknowledge the Sangiran Mandible of 1939 as a female *Meganthropus* as the author claims it to be. Nor do I consider *Pithecanthropus* and *Meganthropus* as two "generically" different and independent hominid types in the taxonomic sense. I shall return to these two points later.

IV. MORPHOLOGY OF THE SANGIRAN MANDIBLE OF 1939

THE SANGIRAN MANDIBLE OF 1939 (Pl. 8e; Pl. 9a–b) is a fragment of the right side of the body extending, along the base, from about the level of the interstice between the second and third molars to the level of the lateral incisor. Not much remains of the alveolar process or of the teeth themselves. Only the first and second molars are *in situ*. The root of the second premolar remains in the bone, while the crown is broken off. The first premolar is missing, but two alveoli of doubtful nature are exposed (Pl. 8, e1, e3; Pl. 9, a1, a1₂, a3). Up to the anterior fracture line of the fragment, the exposed structure of the bone is very difficult to interpret because a great part of this structure seems to have been washed away, leaving only the corticalis, together with a thin, vertical wall (s1, Pl. 9, a3), the superior part of which I regard as the septum between the roots of the canine and those of the lateral incisor. Distal to this wall and between it and the alveoli is a quadrangular projection which is, possibly, the broken root of the canine (r, Pl. 9, a3; r, Fig. 17). At this moment it is impossible to decide whether or not this diagnosis is correct, since I have only the cast. With the original at hand and with skiagrams it will be easy to establish the truth. I shall return to these questions later in the section dealing with the teeth.

A. SIZE

The Sangiran Mandible of 1939 is thicker than the *Pithecanthropus* Mandible B or than any of the *Sinanthropus* or Neanderthal mandibles, but considerably thinner than the *Meganthropus* mandible (cf. Table 6, A). Compared with the living anthropoids, the mandible is thicker than that of any male chimpanzee and only slightly inferior to the minimum values of the gorilla. Yet in each of the landmarks chosen it falls completely within the range of the orang-utan measurements (cf. Table 6, A). The circumference, which can be determined only for the foramen mentale level, confirms the results obtained by the measurement of the thickness (cf. Table 6, C). The height of the symphysis is disregarded because of the fragmentary condition of the front part and because of the uncertainty of any reconstruction. At the other levels Mandible of 1939 does not differ markedly from *Pithecanthropus* Mandible B and *Sinanthropus* Mandible G I. It is lower than that of the smallest gorilla, higher than that of the biggest chimpanzee, but falls within the range of orang-utan.

For reasons previously given, the indices of robustness can be used for comparison only if the mandibles have the same height, or if the indices are proportionately reduced to the same height. If this correction is made, the index does not differ appreciably from that of the *Pithecanthropus* Mandible B or from the Heidelberg mandible.

The thickness of the symphysis cannot be definitely ascertained since the bone is broken at a point lateral to the mid line, but the fragment does reveal that the greatest thickness fell on the torus transversus superior (tts) and not on the torus transversus inferior (tti) (Pl. 8, e2; Pl. 9, a2) as in *Meganthropus* (Pl. 6, b2). From the superior torus to the lower margin the thickness decreases, as the following figures prove: thickness at the torus superior, 19.0 mm.; thickness at the torus inferior, 13.5 mm. This is also shown by a sagittal section through the front part of the jaw just lateral to the symphysis (Pl. 8e). Such a gradual reduction in thickness is characteristic of all anthropoids and is contrary to hominid conditions, which are just the reverse (cf. Fig. 12b–h and l–p). This tapering toward the base, in contrast to the proportions of the *Meganthropus* mandible (Fig. 12j), holds true for the entire body of the Mandible of 1939. At the level of M_2 only, the base is slightly thicker; but at this place the fragment shows traces of a fracture or deformation —a point which will be discussed shortly.

B. SURFACES

1. BUCCAL SURFACE

The buccal surface of Mandible of 1939 (Pl. 8, e1; Pl. 9, a1) resembles that of *Meganthropus* in that in neither is the relief so well developed as that found in the *Sinanthropus* mandible or in those of other fossil hominids. But the surface is not without differentiation. There is a deep, broad groove (d, Pl. 9, a1) at the posterior end of the fragment. This depression is demarcated by a relatively high crest (cr) extending downward and forward from M_2 to the base of the jaw. The crest looks like a continuation of the linea obliqua and the groove behind like the anterior part of the fossa masseterica, but I doubt this interpretation for two reasons. In neither anthropoids nor hominids does the anterior continuation of the oblique line assume the form of a crest, take such a steep course, or reach the very base of the jaw. In no known case do the linea and the masseteric fossae extend forward to the level of M_1. Moreover, the character of the crest, particularly where it crosses the lower margin, suggests that both crest and groove may be the result of a break and are, therefore, accidental. However, I must add a record of interest. In the mandible of the female orang-utan (A.M.N.H., C.A. No. 1811) which has a well-developed digastric fossa, as mentioned in the preceding section (p. 46), the linea obliqua is divided into an inferior crest-like branch with the masseteric fossa behind it and an anterior branch extending to the mental foramen. The entire structure recalls the condition of Mandible of 1939. In this, anterior to the crest, a swelling extends to the mental foramen; it apparently represents the torus lateralis superior (tls, Pl. 9, a1). Above it the alveolar process is slightly depressed and below it is a shallow groove which corresponds to the sulcus intertoralis (si, Pl. 9, a1). Then follows a very slightly projecting basal swelling, the torus marginalis (tm, Pl. 9, a1). Although these depressions and elevations are only faintly indicated, they have the characteristic arrangement of hominid and anthropoid mandibles as described and illustrated in my paper on the *Sinanthropus* mandible.[1] The buccal surface anterior to the mental foramen has a distinct ele-

[1] Weidenreich, 1936.

vation in the region of P_1 but, unfortunately, it is broken off farther forward and upward. This swelling apparently corresponds to a broad alveolar jugum which embraces the roots of P_1 and C (ja, Pl. 9, a3; Pl. 8, e3; Fig. 17). Such a swelling is similarly developed in the *Pithecanthropus* Mandible B (Pl. 8d) and in orang-utans, but is almost completely lacking in *Sinanthropus* and other fossil hominids. At the base the buccal surface is equally rounded, and there is not the slightest indication of either the tuberculum marginale or tuberculum laterale.

The mental foramen (Pl. 8, e1; Pl. 9, a1) consists of a single opening of medium size. This aperture is directed forward and upward, as is usual in anthropoids. It is located in line with the second premolar. (Note the discussion above, p. 36, concerning the *Meganthropus* mandible.) The height at which it is located is like that of the mental foramen of *Meganthropus*. The distance of the foramen from the alveolar plane is 17.5 mm. or 45 to 50 per cent of the total height of the mandible at this level. Consequently, the foramen occupies the same high level as that of the *Meganthropus* mandible. As has been noted, such a high level is characteristic of hominids and, so far, has never been found in any living anthropoid. In modern man the level is about 53 per cent and in anthropoids about 67 per cent of the total height.

2. LINGUAL SURFACE

Although the symphyseal region is broken off, it is evident from the lingual surface that has been preserved that there was a "simian shelf," in other words, a distinct "planum alveolare," and a well-developed torus transversus superior (cf. Pl. 8, e2; Pl. 9, a2). This is contrary to the condition in *Meganthropus* (Pl. 6, b2). The torus superior continues posteriorly into a "prominentia alveolaris" (pa, Pl. 9, a2) which is best developed in line with M_2. Below this projection there is a broad furrow, corresponding to the fossa submaxillaris, to which I have given the more appropriate name of "fossa subalveolaris posterior" (fsp, Pl. 9, a2). The line along which the prominence slopes down to this fossa is marked by a distinct elevation which I consider as a linea mylohyoidea

(lm, Pl. 9, a2). In line with the groove between M_1 and M_2 a fracture crossed the alveolar process, the linea mylohyoidea, and the fossa subalveolaris. Anterior to this fracture and in line with P_1 and P_2, the fossa is a little shallower and wider, apparently representing a "fossa alveolaris anterior" (fossa sublingualis, fsa, Pl. 9, a2). At this place the prominentia alveolaris continues into the torus superior. However, the linea mylohyoidea cannot be traced beyond the fracture with certainty. Although the relief of this region is not clear, it seems to me that the line extends along the fracture to the inferior border of the fossa alveolaris anterior (lm, Pl. 9, a2). In any case, the portion of the lingual surface, as far as it is preserved and can be seen plainly, reveals features which recall the conditions in *Sinanthropus* mandibles, and those of other fossil and recent hominids, far more clearly than in living anthropoids with the exception of the aforementioned female orangutan. Unfortunately, no portion of the lingual surface of the symphyseal region itself has been preserved. It is impossible, therefore, to tell whether or not there was a fossa genioglossi and a spina mentalis. I only venture to suggest that there was a slightly projecting "Basalplatte" (see the description of *Meganthropus*, p. 46).

3. LOWER SURFACE

Unlike the *Meganthropus* mandible, the buccal surface continues into the lingual one with a narrow rounded edge and not with a broad surface (Pl. 8, e2, e4). At the anterior fracture of the fragment and lateral to the mid line, this edge widens in both buccal and lingual directions, but there is no indication of any digastric impression or digastric recessus, the most lateral portion of which should have been preserved if it had been present (cf. *Pithecanthropus* Mandible B, Fig. 8c).

4. TEETH

As I noted above, only the first and second molars are preserved. The crown of the second premolar is broken off, but the root still sticks in the socket (Pl. 8, e1, e2, e3; Pl. 9, a1, a2, a3). In a mesial direction from this tooth, there are two alveoli (al 1, al 2) very close together. I shall consider their interpretation later. Again, a large quadrangular area is mesially placed in relation to the anterior alveolus. This is framed by the corticalis in the buccal direction and by a septum in a mesial (s^1) and distal one (s^2). I regard a smaller, quadrangular mass, adhering to the distal septum, as the broken canine root (r, Pl. 9, a3).

A. First Molar

The first molar is badly worn. The degree of attrition is No. 7, like that of the *Sinanthropus* M_1, depicted in Fig. 142 of my paper on the *Sinanthropus* dentition.[1] The buccal cusps are completely worn off, and the pulp cavity is widely exposed. Only the bases of the lingual cusps remain, with a triangular pit indicating the top of the pulp cavity of the entoconid and a smooth, triangular area distal to it representing the base of the "tuberculum six." Only the buccal part of the pulp pit of the metaconid can be seen, the mesial-lingual corner of the crown with the greater part of the base of the cusp being broken off. The buccal surface of the crown reveals no special pattern, and there is no sign of a cingulum. The remains of the cusps indicate that their location and arrangement correspond to a "*Dryopithecus* pattern," with the metaconid the largest and longest of the five recognizable cusps.

The crown is almost square, the greatest breadth and the greatest length being equal (130 mm. each). The molar rectangle (breadth ×length) is 169. There is no distinct difference between the breadth of the trigonid and that of the talonid.

The root is exposed to a considerable extent (Pl. 8, e1, e2; Pl. 9, a1, a2) on all sides. It is divided into a mesial and a distal branch of which the former is oriented vertically, while the latter deviates in a distal direction. The presence of an undivided portion below the neck is difficult to determine with certainty from the cast, but I have the impression that one exists. The breadth of the mesial branch, at its widest point, is 13.7 mm.; that of the distal branch measures 12.5 mm. The mesial branch appears slightly longer than the distal branch.

B. Second Molar

The second molar is less worn than the first although it, too, has the cusps leveled down to their bases (Pl. 8, e1, e3; Pl. 9, a1, a3). The

[1] Weidenreich, 1937a.

degree of attrition is about No. 5, as in the *Sinanthropus* M_2 depicted in Fig. 161.[1] The pulp pits at the bases of some of the cusps and the fissures between permit the statement that there were three cusps on the buccal side, with the mesoconid pushed considerably beyond the mid line and to the lingual side. There are also three cusps on that side but the two distal ones, the entoconid and the "tuberculum six," are very small, especially the entoconid. Although both are the same length, the protoconid seems to be larger than the metaconid. On account of the mesial shifting of the mesoconid, neither the longitudinal nor the transverse fissures have a typical *"Dryopithecus* pattern." On the contrary, it is a typical "plus pattern," for the four distal cusps are not symmetrically oriented in relation to the mid line. On the buccal surface of the protoconid, a slight indentation in the edge of the occlusal surface is recognizable (Pl. 9, a1). This continues into a fissure on the occlusal surface itself, running parallel to the edge (Pl. 9, a3). This structure apparently represents the vestige of a cingulum, very similar to the fissure found in the same place on the first molar of the *Meganthropus* mandible and described earlier.

The lingual moiety of the main transverse furrow is well preserved, as are the mesial portion of the longitudinal furrow and the furrow between hypoconid and mesoconid, both of which radiate from the transverse furrow. In addition, there are some finer, less complete furrows which indicate the presence of wrinkles covering the metaconid and entoconid. One of these secondary furrows is of particular interest. Together with the lingual moiety of the main transverse furrow, it reaches the lingual surface and separates the distal wrinkle of the metaconid from the rest of this cusp. In fact the wrinkle appears rather like an accessory tubercle, "tuberculum accessorium mediale internum."[2]

Observed from above, the crown has the appearance of a broad square, the breadth (14.3 mm.) exceeding the length (14.1 mm.). The molar rectangle has an area of 205 square mm. The breadths of the trigonid and talonid are the same.

The root, like that of M_1, is exposed on all

four sides (Pl. 8, e1, e2; Pl. 9, a1, a2, a4). It consists of two branches, mesial and distal. The former is stuck in the bone, but the greater part of the latter is broken off, and the stubs are damaged, except for the uppermost lingual part below the neck. As in the root of M_1, the distal branch deviates from the mesial, each branch growing distally. The mesial branch is broader, being 14.0 mm., while the distal branch measures only 11.5 mm.; but the former seems to be longer than the latter. As in M_1, the root may have an undivided portion below the neck.

c. SECOND PREMOLAR

The whole crown down to the neck is broken off; only the root is left (Pl. 8, e1, e2, e3). But since both mesial and buccal surfaces are exposed to a great extent, it is possible to determine the character of the tooth. The buccal surface of the root (Pl. 8, e1; Pl. 9, a1) is divided by a relatively deep and narrow furrow into a narrow distal and a broader mesial portion. The two parts are so close to each other that it is safe to assume that the uppermost portion of the root is single. To judge from the sturdiness and direction of the mesial portion, it would seem that, farther down, the root divides into two completely separated branches, of which the mesial is the longer and stronger. This can be inferred from the most striking peculiarity of the mesial branch. While the distal root descends almost vertically into the alveolus, the exposed portion of the mesial root projects in mesial and buccal direction in a pronouncedly convex form. This indicates that there are two roots and that the alveolus of the mesial root must be located more buccally than that of the distal root. This asymmetry is also shown in the form of the stump. Viewed from above (Pl. 8, e3), the broken surface represents approximately a horizontal cross-section through the neck, that is, the stump has an oval form with its greater diameter oriented in an oblique line which extends from the lingual-distal to the buccal-mesial side. The existence of two roots and their orientation, as just described, are a common occurrence in the premolar of both the gorilla and orang-utan (Fig. 18, P_2). Both *Sinanthropus* and *Pithecanthropus* Mandible B have only one root, but a more or less pronounced asymmetry of the crown is a characteristic feature of the *Sinanthropus* tooth.

[1] Weidenreich, 1937a.

[2] Selenka, 1898, Fig. 90.

D. FIRST PREMOLAR

The first premolar is absent, but its alveolus (Pl. 8, e1, e3; Pl. 9, a1, a3; Fig. 17) is preserved to a considerable extent, and its peculiarities may enable us to determine at least the general character of the tooth. As I stated above, within the alveolar region mesial to the second premolar (Fig. 17) two separate areas, a mesial
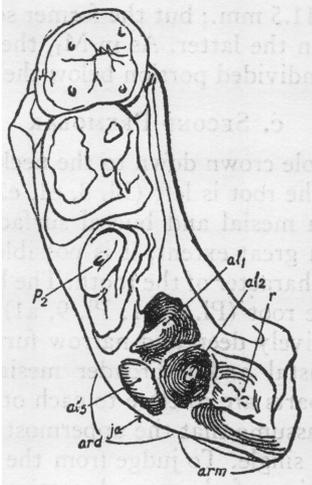

FIG. 17. Sketch of the occlusal surface of the Sangiran Mandible of 1939.

(arm) and a distal (ard) one, can be distinguished. The distal area (ard) embraces two alveoli, a larger distal (al₁) and a smaller mesial (al₂) one, again separated from each other by a thin septum. The distal alveolus (al₁) has the form of a narrow oval, which widens toward the lingual corticalis, and is oriented in transverse direction. It extends almost to the buccal corticalis. The mesial alveolus (al₂) is round and has a more central location; in other words, it is set off from both corticals, except for the mesial-buccal corner which adheres to the buccal cortical. From the size, form, and position of the two alveoli I am inclined to conclude that they are the sockets for the mesial and distal roots of the first premolar. If this interpretation is correct, the tooth was obliquely set into these sockets, the distance from the distal-lingual corner of the distal alveolus (al₁) to the mesio-

buccal corner of the mesial alveolus (al₂) being 17 mm. This would then be a characteristic arrangement and orientation of the first premolar of a sectorial type (see p. 61, below; Fig. 18P₁).

E. CANINE

A stump-like mass rises (Pl. 8, e3; r, Pl. 9, a3; Fig. 17r) from the center of the mesial area (Fig. 17arm) of the broken alveolar region. This is separated buccally and lingually from the alveolar region by the respective corticalis, and mesially and distally by septum-like partitions. It may be that this mass is the broken
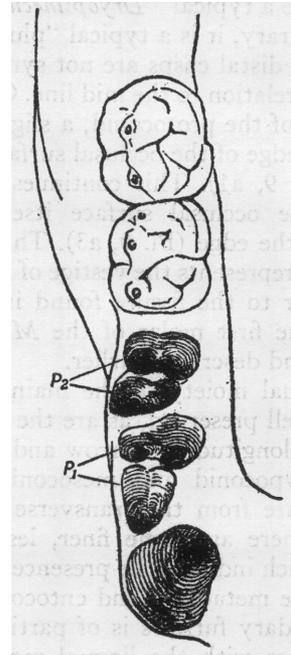
FIG. 18. Sketch of the occlusal surface of a male orang-utan.

and corroded (or otherwise damaged) root of the canine. If this be true, the size of the stump would indicate that the tooth was not particularly large, but it must have been larger than any of the *Sinanthropus* canines or than the canine of the *Pithecanthropus* Mandible B, the alveolus of which is well preserved and available for comparison (cf. Pl. 8d).

C. THE MORPHOLOGICAL CHARACTER OF THE MANDIBLE

The accuracy of my interpretation of the alveoli and the alveolus-like parts as sockets of

the two roots of the first premolar and root of the canine can be determined only by a thor-

ough study of the original and skiagrams taken from it. In any case, the cast itself also permits another interpretation. There is a third pit (Fig. 17al$_3$) toward the buccal portion of the two supposed alveoli of P$_1$ (Fig. 17al$_1$, al$_2$), and just inside of the outer corticalis. It is shallower than the former two and is oriented in a longitudinal direction. It appears to me as if the cancellous tissue of the bone between the outer corticalis and the wall of the alveoli has been washed away, resulting in a pit-like depression. But it is also possible that this depression represents the bottom of the mesial-buccal alveolus of the mesial root of P$_1$. If this should be the case, the large anterior alveolus (Fig. 17al$_2$) should be identified with the alveolus of the canine; and the large mesial area and the supposed stump in its center (Fig. 17 arm, r), with a purely accidental structure formed in place of the alveoli of the two right incisors which have left no trace at all. Should this alternative be correct, the anterior fracture line of the fragment would coincide exactly with a mid-sagittal section through the symphysis (Pl. 8, e2).

The classification of the mandible depends entirely upon a decision on this point. If the first interpretation is correct, the mandible had a sectorial first premolar and a large canine, and therefore must be classified with the anthropoid group. If the second solution is correct, there was a homomorphic canine group, and the jaw is that of a hominid. But certain other features, described above, seem to contradict either of these alternatives. The contour of the mid-sagittal section through the symphysis (Pl. 8, a2; Fig. 12j) harmonizes with an anthropoid rather than with a hominid mandible, whereas the special position of the mental foramen points to the hominids.

In order to facilitate a decision I tried to reconstruct the mandible. But since such an attempt is influenced, under any circumstances, by the interpretation of the doubtful features, the missing parts were intentionally modeled with a moderately sectorial first premolar and a moderately anthropoid canine. Since, under the present conditions, any reconstruction can present only a very rough idea of the general form of the jaw, I limited the reconstruction as follows: the broken crown of P$_2$ was completed; P$_1$ and the canine, with their roots, and the two incisors of the right half were modeled as I

assumed them to have been in nature. The left half of the mandible was added to permit a general judgment on the appearance of the front portion as to the shape of the alveolar arch, should my interpretation prove correct. Mr. Otto Falkenbach again helped me in reconstructing the mandible; the result is shown in Pl. 9b.

As the buccal view (1) and the medial section (5) show, there was only a moderate prognathism. The angle of inclination (Fig. 12j and Table 9) was 54° which is less than that of any of the recent or fossil anthropoids except *Dryopithecus fontani* and *Ramapithecus brevirostris*, but greater than that of any known hominid (in *Meganthropus* the angle is 58°). All told, the type must have been a brevirostral one, whether it was hominid or anthropoid. The alveolar arch (Pl. 9, b 3) exhibits the horseshoe pattern characteristic of hominids. In spite of the clearly pronounced jugum alveolare (Pl. 9, b2) at the level of the second premolar, the outer contour of the alveolar arch has a continuous curve where it turns from the frontal into the side row (Pl. 9, b4). The frontal view (Pl. 9, b2) shows that a distinct though flat incisura submentalis existed. On the other hand, there was a well-developed torus transversus superior (Pl. 9, b3), although there was no "Basalplatte" with similar projection, nor any torus transversus inferior. Neither was there, as already mentioned, any indication of a digastric fossa (Pl. 9, b4) as is characteristic of the hominids and of the special form represented by *Meganthropus*. Furthermore, there is no trace of a spina mentalis, which is to be expected if the jaw is that of a hominid, and the line of fracture coincides with the median section through the symphysis (see p. 38).

Although this lends no support to the idea that the mandible belonged to a hominid, I admit frankly that I am not satisfied with the reconstructed anthropoid pattern of the dentition. There are two reasons for this: first, the canine and also the first premolar, to some extent, have been moved completely from the side row to a frontal position, which is certainly a strange one for an anthropoid canine, as far as our experience reaches. Second, the incisors are too small, and, especially, too narrow for a supposed anthropoid type.

For all the reasons here set forth, the character of the fragment of the Sangiran Mandible

of 1939 cannot be definitely determined from the data available today, which are provided almost entirely by a cast. Should the mandible be a hominid one, it would differ from all that have come to our knowledge up to the present. It could not belong to *Meganthropus*, as suggested by von Koenigswald, even if we resort to explaining the difference in size as a difference in sex. For the differences which remain have proved—as far as we know—to be independent of sex in any anthropoid or hominid. Should the mandible be that of an anthropoid, it would still differ from any known type. I still consider my first opinion to be the most probable, namely, that the jaw belongs to an orang-like anthropoid approaching the hominid pattern to a considerable degree. Considering the problematic character and the imperfect nature of the specimen, on the one hand, and, on the other, weighing the complexity of the problem of Java man to which the discoveries of *Pithecanthropus robustus*, *Meganthropus*, and *Gigantopithecus* have contributed, I deem it best to put aside the Sangiran Mandible of 1939 for the present and to return to it when we have additional and more reliable information.

V. *GIGANTOPITHECUS BLACKI* VON KOENIGSWALD

As I HAVE STATED ABOVE, all that is known of *Gigantopithecus* consists of three teeth: a right and a left lower third molar and an upper right molar. The exact site at which these teeth were found is unknown. Von Koenigswald[1] bought them in a Chinese dispensary in Hong Kong together with the teeth of deer, pig, carnivores, rodents, *Stegodon, Elephas,* and others; primates were represented in the collection by the teeth of a big orang-utan. Von Koenigswald writes: "Although the material lying before this author comes, without any exceptions, from dispensaries, doubtless it originates in China."[2] That von Koenigswald's assumption is correct can be proved by the following facts: the first *Gigantopithecus* tooth discovered, and the only one described and depicted so far, is a right lower third molar.[3] The author failed to state that only the crown is preserved and the root is missing. The same defect occurs in the second tooth, the right upper molar discovered later. The third tooth, the left lower third molar, has only its posterior root; the anterior one is missing. In all three cases the roots have been removed at their bases, very close to the neck. Such a partial or total loss of roots is characteristic of teeth that come from certain caves in South China.

Von Koenigswald's holotype of *Gigantopithecus* is the right lower third molar depicted in Fig. 14,[4] and in Pl. 10c, f, of this paper. The teeth, which he acquired later, the upper molar and the left lower third molar, have been attributed to the same type. The latter tooth (Pl. 10, a1) is undoubtedly the mirror image of the type tooth.

The common character of the three teeth is their enormous size (Pl. 10, a1, b1, c, e1, f, h1; Pl. 11a, b; Pl. 12a, n). As Table 10 shows, they exceed all the known anthropoid and hominid teeth in length, breadth, and height. The maximum values of male gorilla recorded by Remane[5] and listed in Table 10 come very close to *Gigantopithecus,* so far as the upper molar and their mesio-distal and bucco-lingual dimensions

are concerned. This is particularly true for M². But even the largest gorilla teeth are shorter. Unfortunately, except for the lower teeth measured by Gregory and Hellman,[6] there are no records of the heights of anthropoid teeth. Most students took no measurements, for the obvious reasons that most of the teeth available in collections are worn. However, even a small number of unworn teeth can furnish data useful for comparison. This is particularly true of the third lower molar which, in many cases, shows only a slight degree of attrition or none at all. The heights listed in Table 10 are for unworn teeth, except where the figures have been set in brackets. The height differs in each molar; it reaches its maximum on the tips of the cusps and is lowest between them. As will be seen later, these differences vary in each anthropoid group. They are greatest in gorilla and smallest in orang-utan. In *Gigantopithecus,* the height of the crown is extraordinary, at whatever point the measurements are taken, and the differences between the tips of the cusps and the interstices are minimal.

The height of the little-worn, left, third lower molar, taken at the highest cusp (metaconid), amounts to 12.5 mm. The height of the unworn tooth may have attained a little over 13.0 mm. In Table 10, I list the heights of hominid and anthropoid lower third molars obtained from absolutely intact specimens. All are much lower than the *Gigantopithecus* tooth. The gorilla tooth is the highest in my series, but even so, it measures only two thirds of the height of the *Gigantopithecus* molar. The upper molar of *Gigantopithecus* seems to be more worn than the lower. Its height is 12.4 mm.; that of the unworn tooth may have been 13.5 mm. The height of the largest unworn upper molar of the gorilla does not exceed 11.0 mm. In spite of their extraordinary height the teeth of *Gigantopithecus* cannot be classed as "hypsidont," for if the size of the whole tooth is taken into account, the *Gigantopithecus* tooth is not higher, relatively, than hominid teeth. I computed the height in proportion to the length and breadth, as expressed in the length-height and breadth-height indices (cf. Table 10). It is not difficult to determine the length of the lower and upper

[1] Von Koenigswald, 1935, 873.
[2] Von Koenigswald, 1935, 873. (Quotation translated from the original. F.W.)
[3] Von Koenigswald, 1935, Fig. 14.
[4] Von Koenigswald, 1935, Fig. 14.
[5] Remane, 1921.

[6] Gregory and Hellman, 1926.

molars of *Gigantopithecus*, but the breadth is more difficult to ascertain. The lower molar is broadest near the mesial end; from that point it decreases gradually in width toward the distal end. Therefore, the trigonid breadth amounts to 18.0 mm. in the right and to 17.0 mm. in the left specimen, while the talonid breadth is only 15.6 mm. and 14.8 mm., respectively. If the greatest breadth is taken, the height-breadth index is 73.6 for the unworn left molar. This is an extraordinarily high index and far exceeds that of the anthropoids where the maximum may barely surpass 60.0, while the lowest index (orang-utan) is little more than 40. In modern man the average height-breadth index is also below that of *Gigantopithecus*, but there are individual cases in which it considerably exceeds that of *Gigantopithecus*, attaining 80 and over; in the first lower molar depicted in Pl. 10, h4, the index is 82.7.

If, however, the height is considered in relation to the length, the index becomes much lower, amounting to 56.0 against 61.6 in recent man, but only to 33.6 in orang-utan. But this figure cannot be considered as representative of the type, for the third molar of *Gigantopithecus* is extremely long, while it is extremely short in man as well as in orang-utan. The upper molar of *Gigantopithecus*, therefore, furnishes a much more suitable sample for the determination of the height. Its length-height index is 66.3 when the height of the worn tooth (12.4) is taken. Calculated on the basis of an unworn tooth, the index is certainly a little over 70. As Table 10 shows, an index of 70 is about the same as the average for recent man or *Sinanthropus*. Seven unworn upper molars, first and second, from six Mongols and Malayans have an average index of 73.9 with a maximum value of 85.2. Therefore, the great height of the *Gigantopithecus* teeth is in perfect proportion to their total size. The teeth are no more "hypsidont" than those of modern man.

In comparative studies of anthropoid and human teeth, most authors were concerned with the number and general arrangement of the cusps, but gave little attention to their special form or to the character of the enamel which covered the cusps. As I have shown in my paper on the *Sinanthropus* dentition,[1] the so-called "wrinkles" have been almost completely neg-

[1] Weidenreich, 1937a.

lected, because they were widely considered to be unstable, accidental structures and, therefore, of no value for classification. The discoveries of recent years, however, have made us acquainted with entirely new types of anthropoids, hominids, and intermediary types which, as is often the case in paleontology, are represented by teeth only. All these forms possess the same number and the same arrangement of cusps, which Gregory and Hellman designated as the "*Dryopithecus* pattern" and regarded as characteristic of the whole anthropoid-hominid group. Everything learned since then confirms the general validity of Gregory and Hellman's statement. But it has also shown that we must search for other, more special features to serve as clues, in order to distinguish the different types more precisely within the broad "*Dryopithecus* pattern" group.

Branco[2] considered the differences in the height of the cusps and the development of the rugosities of the occlusal surface as essential factors. In regard to the first criterion, he stated that the gorilla has the highest cusps, and those of the chimpanzee and orang-utan were markedly lower, while he found the wrinkles most abundant in orang-utan, less developed in chimpanzee, and absent in gorilla and gibbon. Selenka's[3] statement is more definite. According to him, the gorilla possesses high and cone-like cusps with occasional traces of wrinkles; in the chimpanzee the cusps are not very prominent, but have a great many flat wrinkles distributed over the whole surface; the orang-utan cusps are scarcely prominent, but do have a great many wrinkles separated by deep grooves; in the gibbon, cusps are moderately developed and wrinkles are absent; in modern man the cusps are well developed, though lower than in the gorilla. Although, according to Selenka, wrinkles are rare and weak in man they are more distinct and more abundant in primitive races. *Dryopithecus* is characterized by cusps less developed than in man, but by very distinct wrinkles. Remane[4] has given a very detailed description of the crown pattern of the anthropoid teeth, studying especially the number of cusps and the system of the "crests." In the latter he discerns three categories: 1, sur-

[2] Branco, 1898.
[3] Selenka, 1898.
[4] Remane, 1921.

face crests shown on the chewing surface itself; 2, marginal crests bordering the chewing surface; and 3, basal crests developed on the sides of the crown. The surface crests are divided into two groups, main and secondary. Unfortunately, he failed to furnish a clear diagram of the arrangement of the crests to show the essential differences in the crest systems of the different anthropoid types so that it could serve as a reliable criterion for diagnostic purposes. Remane takes the pattern of the gorilla as a prototype and compares the other anthropoids with it. He concludes that both chimpanzee and orang-utan show a reduction of the main crests and an increase of the secondary crests, a statement which agrees in principle with Branco's and Selenka's views. Doubtless Remane's "surface crests" correspond in the main to the "wrinkles" or "edges" or, more generally, rugosities, described by other authors.

The particular appearance of the rugosities is, in any case, dependent on the form and height of the cusps and the number and arrangement of the fissures (main and secondary) which divide the surface into smaller areas. We will arrive at a clearer understanding of all this if we compare the spread of the enamel over the dentine with the flow and solidification of lava, or, indeed, with the spread and hardening of any other viscid, liquid matter over an uneven surface. For example, in the molars, the cusps of the gorilla (Fig. 19) are high and well-pointed cones, rising steeply from relatively small bases which are separated from each other by deep interstices. The cones are symmetrical and their apexes are located vertically above the center of their bases. In the orang-utan (Fig. 21), the cusps are very low, the apexes are flatter and more rounded, their bases are broad, and their interstices generally narrow. The cones are more asymmetrical, their apexes being closer to the margin of the crown. In the gorilla the central part of the crown (Fig. 19) has the apperance of a deep, narrow, winding valley with side valleys of the same character leading upward from it; in the orang (Fig. 21) the central part is more like a basin drained by a system of many small canals.

The enamel of gorilla cusps (Fig. 19) is carved into fairly sharp crests with deep crevices between them, resembling hardened lava which had traveled straight down a steep in-

cline. The enamel stream exhibits no tendency to extend over the plane surfaces at the end of the incline or to veer from the main direction. The enamel appears as if it had been consolidated after it reached the base of the cone and met the enamel flowing down from the neighboring cones. In the orang-utan (Fig. 21) the enamel stream is quite different. It seems as if it had come down more slowly and with a
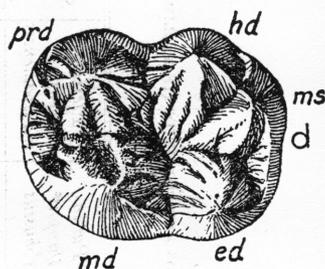
FIG. 19. Right M_1 of a juvenile male gorilla, occlusal view.

FIG. 20. Right M_2 of a juvenile male chimpanzee, occlusal view.

FIG. 21. Left M_1 of a male orang-utan, occlusal view.

greater tendency to divide into smaller, secondary streams over plane areas at the base of the cone. They deviate from the main direction and encroach on territories belonging to neighboring cusps. There are less sharp crests, but more rounded ridges.

While the pattern of the chimpanzee tooth (Fig. 20) shows the general principle of the gorilla type, it differs from that in having lower and less pointed cusps and a more finely carved

TABLE 10

Measurements of the *Gigantopithecus* Molars Compared with Those of Anthropoids and Hominids (in millimeters)

A. Upper Molars

Measurement	Giganto-pithecus		Pithecan-thropus robustus		Sinan-thropus Maxima		Recent Man Average		Gorilla ♂ Average		Orang-utan ♂ Average		Chimpanzee ♂ Average		Paran-thropus[c] robustus		Plesian-thropus[c] transvaalensis		Sivapithecus[e] sivalens		Sivapithecus[e] indicus		Megaladapis[d] Average	
			M¹	M²	M¹	M²	M¹	M²	M¹	M²	M¹	M²	M¹	M²	M¹	M²	M¹	M²	M¹	M²	M¹	M²	M¹	M²
Paracone height	(12.4)ᵃ 18.7		(7.0)	(7.7)	8.3	8.2	8.3	7.5	9.4	10.5	6.5	5.9	6.6	6.2	(7)	8.8	—	—	—	—	—	—	(8)	12.6
Length	16.1		12.3	13.6	12.1	12.2	10.7	9.9	15.1	16.1	12.7	12.4	10.7	10.8	12.3	14	12	12.8	10.7	11.4	11	12.8	19	24.2
Breadth[b]	20.2 ____ 18.0		13.6	15.2	13.4	12.2	11.4	11.3	14.3	15.2	14	13.8	11	11	14.4	15.6	14.6	15	12.2	13.6	12	14.2	16.0	22.2
Length-breadth index[b]	86.3 109 ____ 97.6		111	112	111	100	106.8	114	94.8	94.5	111	112.2	102.8	101.8	117	111	112	117	109	109	109	112	84.2	91.7
Length-height index	66.3		56.9	56.6	68.7	67.2	77.6	75.6	61.7	65.3	51.2	47.5	61.6	57.3	56.8	62.8	—	—	—	—	—	—	—	52.3
Breadth-height index[b]	77.2 60.7 ____ 69.0		51.4	50.6	61.9	67.2	72.8	66.3	65.7	69.1	46.4	42.8	60	56.4	48.6	56.3	—	—	—	—	—	—	—	56.7
Size of rectangles[b]	301 308 ____ 340		167	207	162	149	122	112	216	245	179	171	118	119	177	218	175	192	130	190	132	182	304	537

B. THIRD LOWER MOLAR

Measurement	Gigantopithecus r	Gigantopithecus l	Pithecanthropus Mandible B	Sinanthropus Maximum	Recent Man Average	Gorilla ♂ Maximum	Gorilla ♂ (After Remane)	Orang ♂ Average	Chimpanzee ♂ Average	Paranthropus robustus	Plesianthropus transvaalensis	Sivapithecus sivalensis	Sivapithecus indicus	Dryopithecus darwini	Dryopithecus giganticus	Megaladapis
Metaconid height	(11.4)	12.5	(7.2)	7	6.6	8.2	—	5.2	6.3	7.9	—	—	—	5	8.2	13.6
Length	22	22.3	14.5	12.9	10.7	18	19.1	15.5	12.3	16.2	16.6	13.7	15.8	13.5	19.2	38.2
Breadth: Trigonid	18	17	12.5	12.4	10.8	15.1	17.4	12.6	10.7	14	15	12.3	13.4	11.8	15.5	16.5
Breadth: Talonid	15.6	14.8		12.1		14.8										
Length-breadth index	81.8	75.3	86.2	96.1	99.2	84.2	91.2	81.3	87.2	86.3	91.2	89.9	84.7	87.6	80.7	43.3
Length-height index	—	56	49.6	54.2	61.6	45.5	—	33.6	57.2	48.6	—	—	—	37.1	42.7	35.6
Breadth-height index	—	73.6	57.7	56.4	61.2	54.3	—	41.3	58.8	56.3	—	—	—	42.4	52.8	82.3
Size of rectangles	370	355	181	158	115	270	315	270	315	195	132	168	212	159	298	630

a The measurements of height in parentheses mean that the measured teeth are worn.
b If there is a great difference in breadth between the top and the base of the crown, both figures and the average are given.
c Measurements after Gregory and Hellman, 1939a.
d Measurements after Lorenz von Liburnau, 1905.
e After Gregory and Hellman, 1939a.
f After Abel, 1902.
g After Lorenz von Liburnau, 1905.

TABLE 11

TRIGONID AND TALONID INDICES OF THE THIRD LOWER MOLARS OF *Gigantopithecus* COMPARED WITH THOSE OF ANTHROPOIDS AND HOMINIDS

	Gigantopithecus r	Gigantopithecus l	Gigantopithecus Av.	Sinanthropus Min.	Sinanthropus Max.	Sinanthropus Av.	Pithecanthropus Mandible B	Neanderthal[a]	Recent Man Min.	Recent Man Max.	Recent Man Av.	Gorilla[a] Min.	Gorilla[a] Max.	Gorilla[a] Av.	Orang-utan[a] Min.	Orang-utan[a] Max.	Orang-utan[a] Av.	Chimpanzee[a] Min.	Chimpanzee[a] Max.	Chimpanzee[a] Av.	Dryopithecus[a] Min.	Dryopithecus[a] Max.	Dryopithecus[a] Av.
Trigonid index	81.8	75.3	78.5	84.5	100.6	96.6	86.2	92	80	102	90.7	78.5	89.8	83.5	84.5	93.2	88.7	86.9	89.7	88.8	80	91	84.6
Talonid index	70.8	65.6	68.2	85.3	100	94.2	86.2	87.7	82.5	101.3	88.8	73.1	77.9	75.5	78.7	79.5	79.1	82.5	91.7	87.1	71.4	86	79.4
Difference between both indices	11.0	9.7	10.3	-0.8	+0.6	2.4	0	4.3	-2.5	0.7	1.9	5.4	11.9	8	5.8	13.7	9.6	4.4	-2.0	1.7	8.6	5	5.2

a After Gregory and Hellman, 1939b.

surface. The teeth of early hominids, repre-
sented by *Sinanthropus* (Fig. 22), possess a pat-
tern which resembles that of orang-utan more
closely. They differ in having higher cusps with
more centrally located apexes and a less uni-
formly wrinkled surface. Nor are the single
ridges so flat as those in orang-utan; they pro-
ject more and show, as a whole, greater indi-
viduality. For the arrangement of the wrinkles
and, in particular, their distribution on the
slopes of the cusps, I refer the reader to my
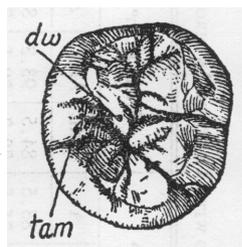
FIG. 22. Right M₁ of *Sinanthropus pekinensis*,
No. 98, occlusal view.
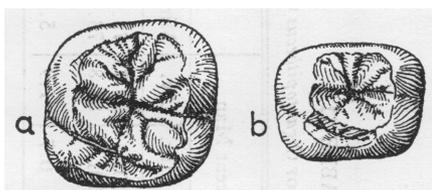
FIG. 23. Subfossil recent man from the volcanic
ashes of the Sangiran District in Java. Upper molar.
Occlusal view.

paper on the *Sinanthropus* dentition, taking the
lower molars as examples.[1] In that paper I
stressed the fact that there is great variability
in the number, form, and size of the individual
wrinkles, but that the principle of their arrange-
ment is always the same; that is, it follows the
general pattern characteristic of an anthropoid
tooth. That description of the main differences
in this pattern holds good only for: 1, intact
teeth or teeth in the process of erupting where
the enamel is completely formed and has not
been affected by wear, and 2, a dentition in
which the wrinkle system of the type in ques-
tion is the best developed.

In the paper on the *Sinanthropus* dentition, I

[1] Weidenreich, 1937a, 80, and Pl. 18, Fig. 155.

also discussed the nature of the wrinkles and
their significance as a criterion for the distinc-
tion of different primate types.[2] Adloff[3] tried to
deny the value of the wrinkles for such a pur-
pose, claiming that these structures are merely
inconstant and accidental irregularities of the
enamel coat of the crown and not an integral
part of the tooth. I was able, however, to prove
that the surface of the dentine underlying the
enamel reveals the same pattern principle as
the enamel itself. The only difference is that
the relief of the dentine is less distinct than
that of the enamel, and only the main crests
and crevices are visible. A cross-section through
any crown with well-developed wrinkles demon-
strates this feature.[4] Since that time, a lucky
discovery by Dr. von Koenigswald has made it
possible to demonstrate the correctness of this
view beyond any possible objection. Von
Koenigswald found subfossil and prehistoric
human teeth (presumably derived from super-
ficial tombs) embedded in volcanic ash, the
enamel of which, although seemingly intact,
was so decomposed by some chemical or physi-
cal agent that it could be completely removed
from the underlying dentine by a fine needle
without injuring the dentine. Fig. 23 shows an
upper molar with the enamel intact (a) and
the same tooth after it had been removed (b).
The crown with the enamel removed is, of
course, smaller than when it was covered by
the enamel layer, but the pattern of the ex-
posed dentine is, in principle, the same; it shows
not only the four cusps, but also the main ridges
and even some of the larger secondary ones.

From this picture it is obvious that the sim-
ile used to compare the relief of the enamel with
lava streams hardened after having flowed over
rugged subsoil is appropriate in that the pat-
tern of the relief depends entirely upon the char-
acter of the underlying dentine. As the dentine,
regarded from the morphological viewpoint, is
the most integral constituent of the tooth, its
surface relief cannot be considered as a purely
accidental feature with no morphological sig-
nificance.

[2] Weidenreich, 1937a, 100–103.
[3] Adloff, 1937.
[4] Weidenreich, 1937a, Fig. 138.

A. THIRD LOWER MOLAR

As the right lower molar (Pl. 10c, f), von Koenigswald's holotype, is worn and lacks all roots, this description is based on the left tooth which shows only slight signs of attrition and has the posterior root completely preserved (Pl. 10, a1, b1, e1, h1; Pl. 11a, b). The pattern of the right tooth, in general appearance as well as in minor details, is the same as for the left one.

The third lower molar exceeds in size any tooth of living or fossil anthropoids or hominids so far known (cf. Table 10 and Fig. 24). This is true for all three dimensions of both crown and root, although the maximum value of male gorilla, recorded by Remane,[1] comes very close to *Gigantopithecus* and may even equal it for the length and breadth of the crown. In addition to the extraordinary total size, the form of the crown has three conspicuous peculiarities.

1. The length exceeds the breadth. It measures 22.3 mm. compared with 17.0 mm., when the greatest, or trigonid, breadth is taken, against 14.8 for the least, or talonid, breadth. The length-breadth index is 75.3. For the right molar the figures are almost the same, but the index is a little higher (81.8) because of its greater breadth (19.0 mm.). That the length exceeds the breadth to such an extent is not an unusual feature among anthropoids, particularly in the third molar. There is, it is true, great variability in this measure, and in the orang-utan and chimpanzee, there is a general tendency toward a decrease, especially in length. This tendency is still more pronounced in the hominids. As Table 10 shows, the length and breadth of the third lower molar are almost equal in modern man (index 99.2), while in *Sinanthropus* (index 96.1) the length exceeds the breadth. In the *Pithecanthropus* Mandible B (index 86.2), however, the length considerably exceeds the breadth, although not so pronouncedly as in *Gigantopithecus*.

2. Its second peculiarity is that the breadth of the trigonid is so much greater than that of the talonid that the occlusal surface almost assumes the form of a triangle with the mesial margin as the base (Pl. 10, a1, c). The trigonid breadth of the left molar is 17.0 mm. and the talonid breadth 14.8 mm. The corresponding figures for the right molar are 18.0 mm. and

15.6 mm. The trigonid index (Table 11) is, therefore, 75.3 and 81.8 mm., respectively; the average is 78.5. The talonid index is 65.6 and 70.8 mm.; the average is 68.2. As is shown in Table 11, both indices are much lower not only than the average indices of any anthropoid or hominid, but also lower than the minimum values. The trigonid index of 75.3 for the left molar is much below the lowest index found in any group listed in the table (78.5 in gorilla), and the talonid index of 65.6 is almost six units below the minimum (71.4 in *Dryopithecus fontani*). The difference between the trigonid and the talonid index is 10 units (right molar) in favor of the trigonid. Differences of the same magnitude, and even greater ones, occur in all the anthropoids; in the hominids the tendency is reversed, toward the increase of the talonid index. Among the anthropoids measured by Gregory and Hellman[2] was an orang-utan in which the trigonid index was 13.7 units more than the talonid index and a gorilla in which the trigonid index exceeded the talonid by 12 units. In modern man the talonid index may exceed the trigonid by 9 units. Such an excess of the trigonid over the talonid breadth cannot, however, be regarded as characteristic of all the molars of *Gigantopithecus*, but it is a peculiarity of the third molar. Neither the first nor the second molar shows such an excess in the anthropoids; in these cases the talonid is very often even broader than the trigonid (see Table 11).

3. The absolute height of the *Gigantopithecus* molar, as mentioned above, is much greater than in any anthropoids or hominids, living or fossil (see Table 10). When, however, the height is considered in proportion to the length and breadth, the condition is different. In proportion to the length, the height is relatively less than in modern man, and only slightly greater than in anthropoids. This is obviously a consequence of the great length of the *Gigantopithecus* molar which exceeds the length of all hominid and anthropoid teeth. When the height is considered in proportion to the breadth, we see that the differences between *Gigantopithecus* and those groups compared with it are still great, although they are not so pronounced as

[1] Remane, 1921.

[2] Gregory and Hellman, 1926.

in the height-length relation. It becomes evident, however, that the height of the *Gigantopithecus* molar is not only absolutely but also relatively great. However, it must be admitted that individual measurements obtained from anthropoids as well as from hominids may approach the *Gigantopithecus* index of 73.6 (Table 10).

The size of the distal root is shown in Table 12. Its height (23.7 mm.) exceeds that of any anthropoid, as do its length and breadth. But the roots of gorilla and orang-utan are not so much smaller, as might be expected at first glance. The greater size, especially in height (Table 13), becomes more striking when the total height of the crown and that of the root

anthropoid. Its extraordinary height is not restricted to that part of the crown which carries the cusps, but involves the entire crown (Pl. 10, h1; Pl. 11, a1). This is not true in other cases; in gorilla the cusps rise high above the general level (Pl. 10, h2; Pl. 11, c1). In *Gigantopithecus*, however, the level of the occlusal surface, as a whole, is very high, and this, again, is the result of the special development of the cusps and their arrangement, both determining the character of the occlusal surface.

All four side surfaces of the crown (Pl. 11a) have the same appearance, but the basal half bulges a little more than the superior half which recedes toward the center of the occlusal surface. There is no clear indication, however, that

TABLE 12

SIZE OF THE ROOTS OF THE *Gigantopithecus* MOLARS COMPARED WITH THOSE OF ANTHROPOIDS AND HOMINIDS
(IN MILLIMETERS)

Measurement	*Gigantopithecus*		*Sinanthropus* Maximum	Modern Man		Gorilla		[Orang-utan		Chimpanzee	
	Ant.	Post.		Ant.	Post.	Ant.	Post.	Ant.	Post.	Ant.	Post.
Height	—	23.7	15.5[a]	14.5	12.9	19.9	16.9	22.2	17.7	12.6	11.6
Greatest length	9	10.4	11.4	4	4.2	5.7	8.6	5	5.4	2.9	4.1
Greatest breadth	17.4	13	10.7	8	6.3	13.6	9.9	11	8.8	5.8	5.5

[a] All M₃ of Sinanthropus have the two roots fused.

TABLE 13

TOTAL HEIGHT (CROWN AND ROOT) OF THE THIRD LOWER MOLAR OF *Gigantopithecus* (IN MILLIMETERS)

Measurements	*Gigantopithecus*	*Sinanthropus* Maximum	Modern Man Average	Gorilla Average	Orang-utan Average	Chimpanzee Average
Height of the talonid and height of the posterior root	35	22.5	18.1	24.2	22	14

are compared. The total height is 35 mm., measured from the occlusal surface of the talonid to the tip of the distal root. In the biggest gorilla tooth I was able to measure, the height was only 26 mm., that is, a quarter less. The third molar of modern man is only half this height, and chimpanzee are still lower, namely, two fifths. The length and breadth of the root are in proportion to the height and, therefore, are also greater than in any anthropoid.

An additional peculiarity in the height of the crown makes it appear higher than that of any

this recession is more pronounced on one side than on the other. Above all, there is no trace of a cingulum or any special basal differentiation, even on the buccal surface (Pl. 11, a1), the usual place where such structures are found in anthropoids and in primitive hominids. The enamel coat of the crown extends down to the division of the root on the buccal side, while it ends a little higher on the lingual side (Pl. 11, a3, a4). On the buccal surface (Pl. 11, a1) two narrow grooves cut deeply into the occlusal border; the mesial one separates the protoconid

block from that of the hypoconid; the distal separates the hypoconid from the mesoconid block. These grooves extend downward nearly to the middle of the surface height. The block surfaces curve inward only slightly toward the grooves proper, that is to say, there are no wide indentations with style-like character such as occur in pronounced form in the gorilla (Pl. 11, c1) and in less marked form in the chimpanzee (Pl. 11, c3) and orang-utan (Pl. 11, c2). On the lingual side (Pl. 11, a2) a special, narrow portion is inserted between the metaconid and the entoconid blocks. The grooves bordering this portion are deep and very narrow, but do not descend so far down on the lingual surface as do the grooves on the buccal surface. On the mesial surface (Pl. 11, a3) there is only a depression between the protoconid and the metaconid blocks. This depression is high on the occlusal margin with two fine indentations on the marginal border, while on the distal surface (Pl. 11, a4) a similar fine indentation separates the entoconid block from "tubercle six."

The occlusal surface (Pl. 10, b1) has the usual pattern of anthropoid or primitive hominid teeth, as far as the number and arrangement of the cusps are concerned. Three cusps form the buccal row, namely, the protoconid (pd), the hypoconid (hd), and the mesoconid (msd). The lingual row is represented by the metaconid (md), the entoconid (ed), and a very small "tubercle six" (t6), jammed between the entoconid and the mesoconid. But there is an additional cusp (tam) between the metaconid and the entoconid. This additional cusp was also present in the right molar (Pl. 10c) where it attracted von Koenigswald's attention.[1] He identified it with the "tuberculum accessorium mediale internum" described by Selenka[2] who found it relatively frequent in orang-utan. Of the five main cusps, the metaconid is by far the largest; the protoconid and the entoconid are about equal and the next in size. Then the hypoconid follows, and the mesoconid, being smallest, is the last. The grooves which separate the cusps are deep and narrow. The metaconid meets the hypoconid through a narrow wrinkle-like prolongation at its mesio-lingual border so that a typical "*Dryopithecus* pattern" is formed.

Before considering the minor details of the occlusal pattern, the special character of the

[1] Von Koenigswald, 1935.
[2] Selenka, 1898.

Gigantopithecus cusps must be discussed. They (Pl. 10, a1) conform to none of those exhibited by the three anthropoids. They differ from those of gorilla (Pl. 10, a2) in having neither high nor steep cones; their tips are not centrally located, nor are the cusps themselves isolated and separated from each other by wide interstices. They differ from those of the chimpanzee (Pl. 10, a4) in the same characteristics and from those of the orang-utan (Pl. 10, a3) in being more individual and not fusing into one shallow basin with their tips reduced to slightly elevated points at the marginal border of the occlusal surface. The *Gigantopithecus* cusps rather conform to the hominid type as represented by *Sinanthropus* (Pl. 10, b2, b3, b4) and certain Neanderthalian molars (Pl. 11f). They appear as broad-based tubercles with rounded tips and gently declining slopes. As in hominid teeth (Pl. 10, b5, b6), the grooves which separate their bases are deep and narrow. The wrinkle system has the typical hominid pattern. The wrinkles are relatively fewer than in orang-utan, and there are fewer secondary ones, but they are individually larger. They do not look like sharply carved straight ridges as in gorilla (Pl. 10, a2) and chimpanzee (Pl. 10, a4), but all have smooth contours, and their rounded and broadened ends have a tendency to deviate, more or less, from their original directions. For this reason the furrows between the cusps appear as rather sinuous lines.

The special pattern formed by the cusps and systems of grooves and wrinkles in the *Gigantopithecus* molars (Pl. 10, b1) more nearly resembles that of the hominids than does that of any of the anthropoids. There is a distinct fovea anterior (fa), but no fovea posterior. The latter is replaced by "tubercle six" which is situated between the mesoconid and the entoconid and marks the end of the longitudinal groove which is divided in front of the tubercle into two fine fissures. The metaconid is not only longer but also broader than the protoconid, so that the mesial section of the longitudinal groove is closer to the buccal side. The metaconid has a large, well-developed, median wrinkle (dw, Pl. 10, b1) which emerges from the tip, extends in the direction of the protoconid, and there forms a right angle distally. It traverses the groove between the protoconid and the hypoconid and meets the mesial wrinkle of the entoconid approximately in the center of the oc-

clusal surface. The latter deviates sharply in a mesial direction after having made contact with the hypoconid. I know very well that there is a great variability in the size and course of the wrinkles and that, for this reason, their special arrangement in the lower *Gigantopithecus* molars—although it is nearly the same in the left and right ones—cannot be regarded as absolutely characteristic of the type. But the character of the "deviating" metaconid wrinkle which makes the contact first with the protoconid, then with the hypoconid and the entoconid, is so strikingly like that in some *Sinanthropus* molars (dw, Pl. 10, b2, b3) and modern man (Pl. 10, b6) that it seemed worth describing in detail. The undeviated upper portion of the metaconid wrinkle, and the mesial protoconid wrinkle correspond to the two ridges which, in anthropoids, form the "trigonid crest." In the *Gigantopithecus* molar, as in the hominids, there is no such crest. It is only faintly indicated by the transverse swelling formed by the two wrinkles, and by a short break in the longitudinal furrow where it passes over the top of this swelling (cf. Pl. 10, a1, b1).

The "tuberculum accessorium mediale internum" (tam, Pl. 10, b1) noted by von Koenigswald[1] in his brief description of the worn, right lower molar (Pl. 10c) has the appearance of an isolated wrinkle cut off from the metaconid or the entoconid. It is restricted to the marginal border and has sunk between the two cusps, from each of which it is separated by a deep and narrow furrow which extends over the superior half of the lingual surface. A deeper and wider groove separates it from the juncture of the two deviating metaconid and entoconid furrows. The occurrence of an isolated tuberculum, located at the marginal border between metaconid and entoconid, has been recorded by Selenka[2] in a great many specimens of orang-utan. The author found it in the third lower molars of 18 per cent of the males and in 26 per cent of the females. According to Remane's[3] statistics this greatly exceeds its incidence in chimpanzee where it occurs in only 7 per cent. Some of this disproportion is apparently due to uncertainty as to which structure should be designated as the

"tuberculum accessorium" in orang-utan. In Selenka's paper[4] the tuberculum is not indicated in the idealized dentition of the mandible of orang-utan, or in the idealized figure of the first lower molar given as an example of an orang-utan tooth.[5] However, it is shown in the photographs of the dentition of an adult male orang-utan.[6] In Fig. 96 which displays, according to the caption, "all the accessory cusps which occur," a supernumerary cusp, which may be the tuberculum in question, may be seen in the right second and third molars. In the second molar this is very small, while in the third molar it is the size of the entoconid. None of the orang-utan specimens at my disposal had a distinct supernumerary cusp as shown in Selenka's figure. But it must be taken into consideration that the cusps of the third molar in Selenka's case are worn down almost to their bases, whereas in intact teeth their individuality is more concealed by the abundance of large and small fissures. This makes it very difficult to determine, sometimes, to which cusp one wrinkle or a group of wrinkles should be attributed. In particular, there is often no sharp boundary between the metaconid and the entoconid. Instead, there is a group of wrinkles —sometimes larger, sometimes smaller—arranged in transverse direction which reach from the hypoconid to the lingual marginal border where they may be marked by fine indentations. In the third lower molar of a fossil orang-utan which comes from a cave in Kwangsi (South China) and which is depicted in Pl. 10, a3, the continuation of the fissure separating the metaconid block (md) from the entoconid block (ed) at the lingual surface also indicates the limits between the two cusps at the occlusal surface. But in mesial direction from this fissure, a small area consisting of two transverse wrinkles is separated from the metaconid by a very pronounced fissure deviating from the main longitudinal fissure. This may represent the "tuberculum accessorium mediale internum." In the third molar of the gorilla, where, according to Remane,[7] the tubercle occurs in 35 per cent, the tuberculum is represented in unworn teeth by a small cone rising directly from the

[1] Von Koenigswald, 1935.
[2] Selenka, 1898.
[3] Remane, 1921.

[4] Selenka, 1898, 125, Fig. 141.
[5] Selenka, 1898, 127, Fig. 159b and c.
[6] Selenka, 1898, 74, Figs. 94–96.
[7] Remane, 1921.

marginal crest (tam, Pl. 10, a2). In the gorilla tooth depicted in Pl. 10, e2, there is no special cone, but its position is indicated by a broad interstice between the metaconid and the entoconid. This space is occupied by a double-contoured and slightly elevated marginal crest. In the chimpanzee tooth depicted in Pl. 10, a4, no accessory tubercle is recognizable.

In *Gigantopithecus* (Pl. 10, b1) the aspect of the tubercle (tam) differs widely from its appearance in the three anthropoids. Its marginal position indicates that it must be regarded, primarily, as a differentiation of the marginal crest. This crest never appears as so distinct a structure in *Gigantopithecus* as in the unworn molars of gorilla (cf. Pl. 10, a2) and chimpanzee or in the worn molars of orang-utan; nor does it matter whether the tooth is intact as in the left molar (Pl. 10, b1) or worn as in the right molar (Pl. 10, c1). Its appearance conforms to the compact block character of the *Gigantopithecus* cusps, which can be compared only with that of primitive hominids. It is true that no *Sinanthropus* molar has yet been found, nor has one been found in Neanderthal man, which shows the tuberculum accessorium to be so well developed as it is in *Gigantopithecus*. But there is no doubt that very similar conditions can exist in hominid teeth. I do not mean merely that an accessory tubercle may be found inserted between the metaconid and entoconid; I mean that there is a deviation from the normal number and arrangement of the cusps and a similar "disturbance" of the wrinkle system within the area indicated. In no fewer than three unworn or slightly worn lower molars of *Sinanthropus*, the border region of metaconid and entoconid exhibits those "disturbances." In the *Sinanthropus* M_1, No. 98 (Fig. 22), the deviating metaconid wrinkle extends in distal direction and meets a specially developed hypoconid wrinkle and another one emerging from the entoconid, almost in the center of the surface. Furthermore, a marginal area (tam) is completely separated from the metaconid. This area consists of two wrinkles, a short mesial and a longer distal one, both demarcated by slight indentations at the marginal border. Very similar conditions are found in the *Sinanthropus* M_2, No. 44 (Pl. 10, b4); this also has a distal portion separated from the main part of the metaconid; this special division has de-

veloped a large transverse wrinkle extending toward the center of the tooth. *Sinanthropus* M_1, No. 36 (Pl. 10, b3), also exhibits conditions similar to those of *Gigantopithecus*. Here the big metaconid wrinkle (dw) bends in a sharp distal turn and runs into two entoconid wrinkles which are directed both mesially and buccally. In the lingual direction are two smaller wrinkles which emerge from the marginal border and run in transverse direction toward the spot where the metaconid and entoconid wrinkles meet. These marginal wrinkles (tam) appear as a distal portion of the metaconid. Superficially they are separated from this cusp by very fine furrows which slightly indent the marginal border. This group apparently represents a small tuberculum accessorium. In *Sinanthropus* molar No. 137 (Pl. 10, b2) protoconid and metaconid, especially, show—as does also the fovea anterior—the same details as the *Gigantopithecus* molar; the only difference is that the area of the accessory tubercle appears less "differentiated."

In the molars of Neanderthal man (Pl. 11f) the characters of the cusps and the wrinkle system are the same as in *Sinanthropus*, although the wrinkles are less numerous and less distinct. In the worn Krapina first lower molar (Pl. 11, f2) there is no accessory tubercle, but some small wrinkles emerge from the marginal border between metaconid and entoconid. Even in modern man (Pl. 10, b6) where the continuing reduction of the number of the cusps and the whole wrinkle system is far advanced, and where the entire tooth form is changed, cases can be found where the metaconid-entoconid-hypoconid group has the same appearance as in the *Gigantopithecus* molar (see p. 82).

The posterior root of the *Gigantopithecus* molar (Pl. 11a) emerges almost directly from the crown without the interposition of an undivided portion. There is, therefore, no "body," as Keith[1] named this part of the root. The root divides into an anterior and posterior branch immediately at the neck. Another term used by Keith to designate the condition observable in the *Gigantopithecus* molar is "cynodontism." This is used in contrast to "taurodontism." "Taurodontism," according to the same author, signifies the persistence of a smaller or larger undivided body of the root, as is characteristic

[1] Keith, 1913.

of *Sinanthropus* (cf. Pl. 11d) and most of the Neanderthalians. Taurodontism is, therefore, an undivided root portion combined with a large pulp cavity. The younger the tooth the larger the cavity.[1] Since no skiagram of the *Gigantopithecus* molar is available, it is impossible to say certainly whether "taurodontism" exists in this case. But as there is no "body," the tooth must be classed among the "cynodont" teeth like the lower molars of anthropoids and modern man, if Keith's classification and argument are accepted without reservation. As far as the cast permits judgment, the pulp cavity, partly exposed where the anterior root has been severed from the crown (Pl. 11b), is large when compared with the size of modern human teeth. But it does not seem particularly large when the enormous size of the entire tooth is taken into account. In the right *Gigantopithecus* molar where the entire root including its base is missing, the pulp cavity of the crown is completely exposed. It is filled, however, with a substance, the nature of which cannot be determined so long as the original is not available. Possibly the substance is a deposit of secondary dentine. Considered as a whole the cavity is large and the enclosing walls are relatively thin.

The distal root which is preserved deviates from the base of the anterior root in distal direction and is curved in the same way, throughout its entire length (Pl. 11a). Its distal surface is strongly convex, whereas the mesial one is flat or slightly concave. A furrow, deep at the base of the root but flattening toward the apex, divides the mesial surface into a broader buccal and narrower lingual portion and then continues to the apex which it divides into a bigger, longer buccal tip and a smaller, shorter lingual one (Pl. 11, a2, 3). The latter is shifted a little toward the mesial side. The general impression is that the entire root is formed by the fusion of two branches: a larger, buccal, distal branch and a smaller, shorter, mesial one. Between the neck of the tooth and the vertex of the concavity of the distal surface of the root is a broad, shallow groove which is best developed around the lingual mesial border of the root (s, Pl. 11, a1, a4).

[1] For further data the reader is referred to the paragraph on taurodontism in my paper dealing with the *Sinanthropus* dentition, 1937a, 103–109.

The mesial root is missing; only its base is preserved at the neck (Pl. 11, a2, ab), so that the only information obtainable concerns the dimensions in mesio-distal and bucco-lingual directions. The figures listed in Table 12 show that the mesial root was a little narrower in mesio-distal direction, but considerably broader in bucco-lingual than the distal root: 9.0 mm. against 10.4 mm. in the first case and 17.4 mm. against 13.0 mm. in the latter.

In the third lower molar of gorilla, the distal root shows the same characteristics (Pl. 10, h2). It deviates distally; is strongly curved with the convexity directed distally; the mesial surface is concave with a longitudinal furrow dividing it into a broader buccal and a narrower lingual portion. The apex is separated into two tips, and the lingual one is the longer. There is also a deep narrow furrow between the neck and the very pronouncedly convex distal surface. The mesial root is considerably smaller in mesio-distal direction than the distal root, but greater in bucco-lingual direction. In orang-utan the distal root deviates more than in gorilla, but is straight or only slightly curved. Its distal surface is convex and the medial one concave, with a longitudinal furrow dividing it into two almost equal parts. The tip is double, the lingual point being the larger and longer, as in gorilla. In mesio-distal direction, the distal root is only slightly, if at all, larger than the mesial root, but is distinctly smaller in bucco-lingual direction. There is only a very slight transverse furrow below the neck. The chimpanzee shows the same condition as the orang-utan, and while the differences between the two roots are recognizable they are much less pronounced than in orang-utan.

According to Remane[2] the distal root of the third molar of gorilla is narrower than the mesial; its distal surface is quite rounded and shows no longitudinal furrow, producing a kidney-shaped cross-section. Usually this root is strongly developed and diverges distally. Remane also says that the distal root of the third molar of the orang-utan and particularly of the chimpanzee is, in general, less developed and less divergent from the mesial root than is the case in gorilla. Otherwise, he says, it shows the same characteristics.

[2] Remane, 1921.

In modern man, the distal root, if not fused with the mesial as is usually the case, also deviates distally. It looks like an attenuated cone with a tapering end. The longitudinal furrow on the mesial surface is only faintly indicated. According to Adloff[1] the third molar of man has two roots, a larger mesial and a smaller distal one. Both roots are flattened in mesio-distal direction, and the mesial root usually has a longitudinal furrow. The differences in the dimensions between the mesial and distal roots are, therefore, the same in man as in *Gigantopithecus* and the anthropoids, but much more pronounced. In *Sinanthropus* the roots of all the third lower molars available are either undeveloped or are so fused that we know nothing of the form of the distal branch or about the differences between the latter and the mesial branch.

B. UPPER MOLAR

It is relatively easy to identify the two lower molars of *Gigantopithecus* described in the preceding section as third molars. Their elongated triangular shape is characteristic of third molars of those higher primates in which these teeth have not undergone a clear reduction in size and form as they did in *Sinanthropus* and man. But there is no such clear indication as to which of the three upper molars the *Gigantopithecus* molar belongs. The only clue we have is the size of the hypocone in relation to the other three cusps, especially to the metacone. The hypocone is about the same size as the metacone, which excludes the possibility that the tooth is a third molar, since in all higher primates, including man, the hypocone shows a tendency toward reduction proceeding from the first to the third molar.[2] The equality in size of the hypocone and metacone indicates, therefore, that the tooth is either a first or second molar, with the probabilities in favor of its being a first molar.

The extraordinary height of the crown has already been discussed. A comparison of the dimensions with those of anthropoids and man, particularly the respective ratios between the height and the length or breadth, shows that, in man, these ratios are likely to be a good deal higher than in *Gigantopithecus*. (See Table 10, length-height index, 66.3 against 77.6 or 75.6 in average man; and height-breadth index, 77.2 or 60.7 against 72.8 or 66.3 in average man.) As in the lower molar, the height of the crown is nearly uniform; the occlusal surface is almost

[1] Adloff, 1908.
[2] Cf. Vram, 1898.

a plane, and even the tips of the cusp do not rise much above the level, although both the paracone and the metacone are unworn (Pl. 12, a2, n1, n2, n3, n4).

In the form of the crown, there is a striking contrast between the orientation of the buccal and lingual surfaces (Pl. 12, n3, n4). While the former is vertically orientated with the tips of the paracone and metacone perpendicularly below the buccal margin of the base of the crown, the lingual surface recedes pronouncedly in buccal direction. Its angle with the base is about 70° as against 90° at the buccal surface. A similar condition can be found in the gorilla and, to a lesser degree, in the chimpanzee; the right M[2] of *Pithecanthropus robustus* also shows this condition of the lingual surface (Pl. 3d). The mesial and distal surfaces of the *Gigantopithecus* tooth (Pl. 12, n1, n2) are in an almost vertical position, the distal surface a little inclined, and the mesial one slightly overhanging. The basal half of the *Gigantopithecus* crown is bulging. This is particularly noticeable on the buccal surface, less so on the lingual one. This bulging is the only feature which can be interpreted as representing a remnant of the cingulum.

The limits between the four cusps are indicated by more or less pronounced narrow indentations on the four sides. Viewed from the sides, however, the cusps do not appear as cones carved from the side surfaces, an appearance characteristic of the upper molars of anthropoids (cf. Pl. 12d–f). This is particularly true of the buccal and lingual aspects (Pl. 12, n1, n2). In the *Gigantopithecus* molar the crown,

viewed as a whole, appears more like a single square block than as a block composed of four joined cones (Pl. 12, n1, n2, n3, n4).

The occlusal surface of the molar (Pl. 12a, b) can best be visualized by quoting literally (leaving out only some special features which will be discussed later) Mummery's description of the first upper molar of recent man.[1] The terms used by him for the cusps and directions have been replaced by those now current in paleontological papers. Mummery says:

The occlusal surface is in the form of a rhomboid, the mesio-lingual angle being rounded off and less well marked than the others. The mesio-buccal and disto-lingual angles are acute, the paracone extending farther mesially than the protocone while the hypocone is distal to the metacone. . . . The proto-cone is broad and rounded; it is blunter than the outer cusps and considerably larger. It is separated from the hypocone by a fissure and is connected with the paracone by a prominent ridge . . . . and is also separated from the paracone by a deep fissure. . . . The paracone is convex and the outer surface of the crown and its mesial margin is continuous with that of the protocone . . . . It is separated from the metacone by a fissure which is continued on the buccal surface at the crown. The hypocone is the smallest; it is convex on the lingual surface and a ridge produced from its summit forms the prominent distal border of the occlusal surface and is continuous with the ridge connecting it with the metacone. At its base it is separated from the protocone by a deep fissure. . . . The lingual end of this fissure is continued upon the lingual surface of the crown terminating at a point about half-way to the cervical border. The metacone is of about the same size as the paracone. It is separated from this by a fissure which is continued about half-way across the buccal surface of the crown. Distally it joins the elevated distal margin of the crown. . . .

In this description only four sentences have been omitted. These refer to the "oblique crest" which unites the protocone with the metacone by crossing the occlusal surface from the mesio-lingual (protocone) to the disto-buccal (meta-cone) corner. Mummery considers this ridge a distinct feature of the human upper molar, obviously following Topinard[2] in this characterization. Topinard regarded the kind of union between protocone and metacone in man as a more characteristic feature than the number of

[1] Mummery, 1924.
[2] Topinard, 1892.

the cusps, and he even blames the earlier anat-omists for neglecting its existence. According to Topinard the oblique crest is sometimes continuous, sometimes interrupted, more or less, by a superficial or deep furrow which traverses the saddle. I shall return to this feature later, but for the moment it is sufficient to state that there is no indication of such a crest in the *Gigantopithecus* molar. On the contrary, meta-cone and protocone are separated from each other by a distinct furrow traversing the entire distance between the two blocks.

To complete the description of the occlusal surface of the *Gigantopithecus* molar, some details must be added. Of the four cusps, the two buccal ones (paracone and metacone) are higher than the two lingual ones (Pl. 12, n3, n4), attrition having only slightly affected the former. The most conspicuous differences between the two sets of cusps, however, is a peculiarity of the paracone and metacone which gives them the appearance of being wrapped, on their outer sides, in special "sheets" (Pl. 12, a2). These "sheets" begin as thin, marginal edges at the mesial side of the fissure between protocone and paracone. They continue, without changing character, to the opposite (distal) side where they completely lose their identity at the fissure between metacone and hypocone. The cones which represent, as it were, the cores of the cusps have a special feature of their own. The area of the paracone seems to be slightly fur-rowed by fine, outward-curving grooves which extend from the tip of the cone toward the base. This is a typical wrinkle system and gives the cusp a peculiar individual appearance, as if it were an opening flower bud, for which reason I shall refer to it as the "flower-bud pattern" (fb). In the metacone the wrinkles are less distinct, but larger, and the relief of the cone prop-er resembles a clover leaf, and so may be called the "clover-leaf pattern" (tf). After becoming familiar with the patterns of paracone and metacone one finds, when observing the protocone and hypocone, that these cusps have, in general, the same pattern as the metacone. The only difference is that the relief is lower and obscured. I believe that this is an actual condition and not the result of attrition. Each cusp has the flanking marginal edges and the core between, spreading toward the intercuspidal fissures in small, flattened lobes (Pl. 12, a2).

The remote prototype of this entire cusp pattern is best observed in the gorilla (Pl. 12d). This shows the wrinkle system in its typical form and arrangement, but there are great differences in character, some more general, some more specific, between gorilla and *Gigantopithecus*. In gorilla the cusps are much higher and, therefore, the descending crests and wrinkles are steeper and more sharply carved. The tips of the cones are in a vertical line above the center of their bases and not at the exterior margins as in *Gigantopithecus* (cf. also the conditions of the lower molar described above). The oblique crest (co), well developed in gorilla which extends from the tip of the metacone to that of the protocone, is entirely absent in *Gigantopithecus*, as mentioned above, where the two cusps are completely separated. But in *Gigantopithecus* another wrinkle connects the protocone with the paracone. This is a sinuous fold which detaches itself from the buccomesial border of the protocone and meets the marginal edge at a mesial point where it drops down from the paracone. A comparable wrinkle, although smaller, is recognizable in gorilla also, as may be seen in Pl. 12d.

Of the four fissures separating the cusps of the *Gigantopithecus* molar from each other, the two which mark the boundaries of the metacone are the widest and deepest (Pl. 12, a2). One of these main fissures, the distal fissure, separates the metacone from the hypocone; the other, the buccal fissure, separates the metacone from the paracone. The distal main fissure subdivides into a buccal and a lingual sub-branch. The buccal sub-branch which separates the metacone from the protocone is clearly marked; the lingual sub-branch between hypocone and protocone is less well developed. The main buccal fissure meets the buccal sub-branch, which deviates from the distal main fissure, almost in the center of the surface where paracone, metacone, and protocone join. From that point the buccal sub-branch continues into a mesial sub-branch which separates paracone and protocone. There is neither a fovea anterior nor a fovea posterior in the strict sense. The positions of both these features are indicated by short secondary fissures. The fissure indicating the position of the fovea posterior separates the distal marginal edge from the adjacent masses of metacone and hypocone. The fovea anterior is indicated by a shorter fissure which separates the mesial marginal edge from the adjacent bodies of paracone and protocone.

The root (Pl. 12, n1, n2, n3, n4, n5) is broken off short at the neck; it is impossible to tell whether the enamel extended farther down on one side than on the other. Nor are there any indications as to the size of the root branches. The only deduction that can be made from the appearance of the fracture (Pl. 12, n5) is that one branch (br) descended from the entire lingual side of the neck, and that two branches descended from the buccal side, the mesial branch (bmr) being the stronger and projecting farther in mesial direction than the distal branch (bdr) in its own direction. As far as the cast permits judgment, a large pulp cavity (cp) occupied the basal part of the crown.

C. CHARACTER OF THE TEETH

Von Koenigswald designated the third right lower molar found first as the type of "*Gigantopithecus*," considering it, as the name indicates, as a giant ape, but he is very diffident in attributing the tooth to any special group. He wrote:

The enormous, rather worn, third lower molar cannot be ascribed to *Simia*. Not only are the abundant wrinkles, typical of *Simia*, completely wanting, but the tooth is distinguished by a peculiar super-development of accessory cusps which gives it an aspect somewhat strange for a primate tooth.[1]

[1] Von Koenigswald, 1935.

But since Selenka had described similar accessory cusps in orang-utan, von Koenigswald seems to be inclined to place the tooth in the neighborhood of orang-utan, and finally remarks: "I cannot allocate our tooth to any one of the known primates." Furthermore, although he admits that the general pattern of the *Sivapithecus* teeth differs from that of *Gigantopithecus*, he finds some resemblance to *Sivapithecus middlemissi* described and figured by Pilgrim[2] and concludes with the surmise that

[2] Pilgrim, 1927.

"*Gigantopithecus* may belong to a side branch of the *Sivapithecus* group."

Gregory and Hellman[1] and Broom,[2] the only authors who have referred to *Gigantopithecus* since von Koenigswald's first publication, do

Fig. 24. Millimeter graph showing the size of the M_3 and M^1 of *Gigantopithecus*, *Meganthropus*, *Pithecanthropus robustus* and *erectus*, *Sinanthropus*, and recent man.

not question its anthropoid character. Broom considers *Gigantopithecus* as a special side branch of his family tree of higher primates, placing it between the hominids and anthropoids preceding the Australopithecinae branch-off. According to Gregory and Hellman, who

[1] Gregory and Hellman, 1939b.
[2] Broom, 1939a.

had access to a cast of the upper molar of *Gigantopithecus*, this form shows fundamental resemblances to the upper molar of *Paranthropus*, on the one hand, and to that of orang-utan, on the other. But the authors do not give details of the nature of these resemblances.

When I saw the original of the holotype of *Gigantopithecus*, the worn right lower molar, I did not question the general anthropoid character of the tooth. But when von Koenigswald sent me a cast of the almost unworn left lower molar, acquired later, doubts arose. Superficial comparison with the scant material of fossil anthropoids, then available to me in the Peking laboratory, suggested that the teeth were not those of an anthropoid but of a true hominid. Thorough comparative investigation with all the anthropoid material, both living and fossil, later at my disposal, convinced me that this suggestion was correct. Indeed *Gigantopithecus* has been misnamed; it should have been called "*Gigantanthropus*."

Before entering into a discussion of the human character of the *Gigantopithecus* teeth, it seems expedient to discover, first, whether or not there is any *a priori* objection to the possibility that the teeth belong to a hominid. Of course, there is, above all, the size. The measurements in Table 10 and the graph (Fig. 24) prove that the upper and lower molars far exceed the size of any human tooth, fossil or living, so far known; they considerably exceed even the corresponding teeth of the largest living and fossil anthropoids. If the mass of the crowns is calculated on the basis of height $\times$ length $\times$ breadth of the crown, the upper molar of *Gigantopithecus* approaches a cube; its mass amounts to about 4170 cu. mm; that of the average modern man is 926 cu. mm., and the maxima measurements are only 1526 cu. mm. The mass of the crown of the upper *Gigantopithecus* molar is, therefore, more than four times greater than that of the average modern man and three times as large as even the largest teeth ever observed in modern man. For the third lower molar the corresponding figures are 4420 cu. mm. for *Gigantopithecus* and 723–1450 cu. mm. for modern man. The *Gigantopithecus* molar then is almost six times larger than that of the average modern man and three times larger than the biggest teeth of anthropoids and man ever recorded. In such a com-
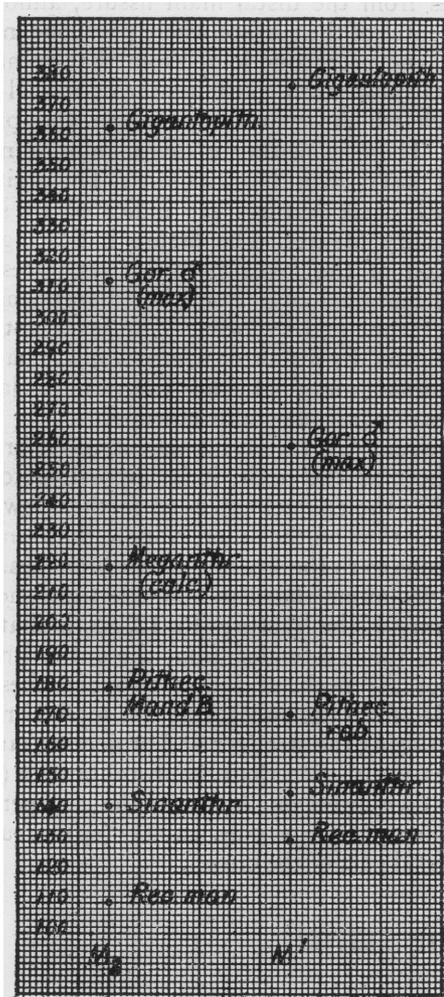
parison however, it must be remembered that the third lower molar is reduced in the majority of cases in modern man. Compared with the largest gorilla teeth, the crown mass of the

When, instead of the volume of the molar crowns, only the rectangles (the length and breadth dimensions) are computed, the enormous size of the *Gigantopithecus* molars compared
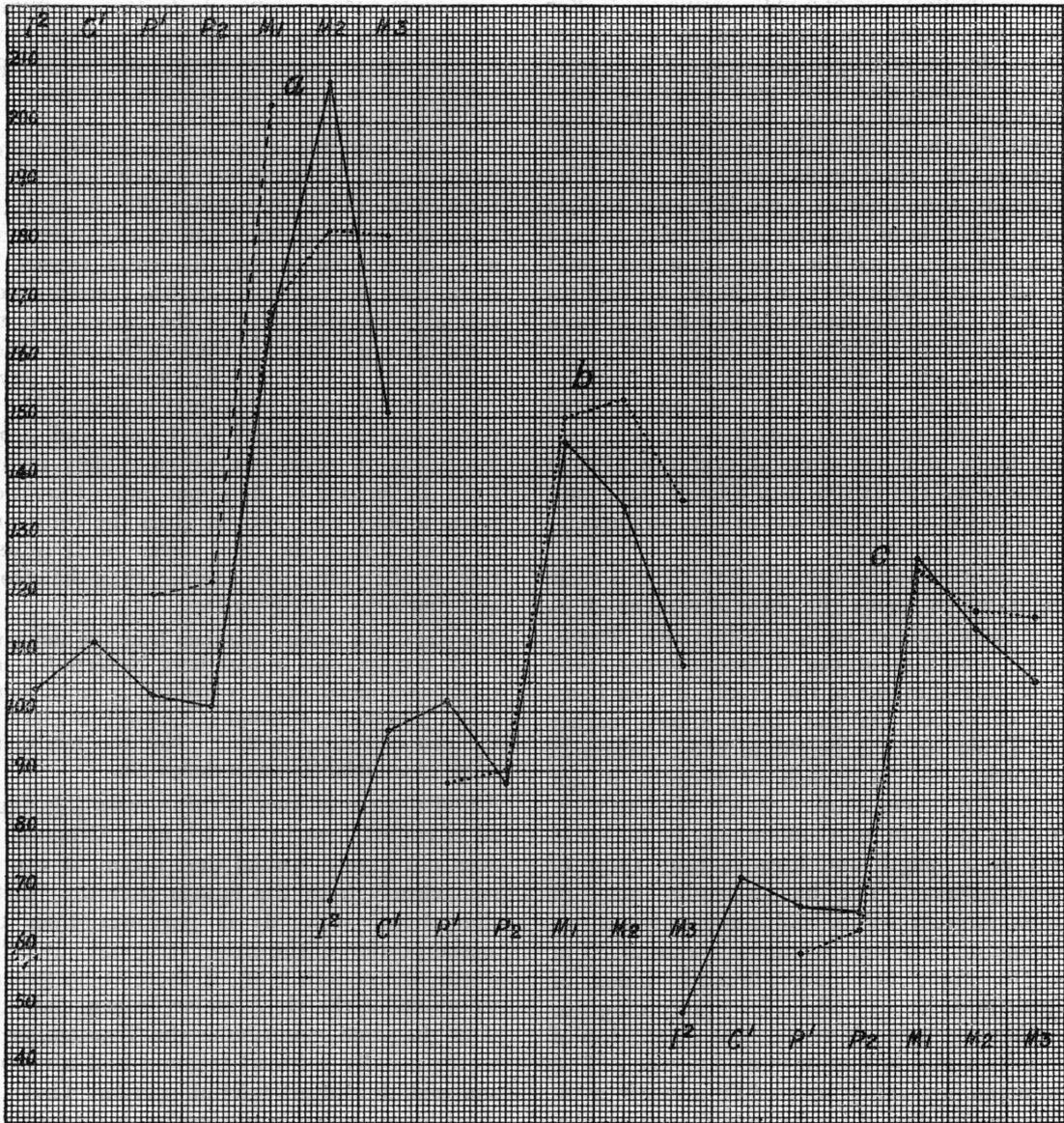

FIG. 25. Millimeter graph showing the size of the upper and lower teeth of fossil and recent hominids as represented by their rectangles. (See p. 100.)

upper and lower molars of *Gigantopithecus* is each about twice as large as that of gorilla: M^2 of gorilla is 2370 cu. mm.; M_3 is 2356 cu. mm.

with that of other hominids and the maximal values of a male gorilla is no less impressive. In Fig. 24 the size of M_3 and M_1 is marked on a millimeter scale according to the computed

square millimeters. M_3 of *Gigantopithecus* at the top of the scale (363) is more than three times larger than that of recent man (110), almost three fifths larger than the calculated value of *Meganthropus* (220), and one sixth larger than the maximum value of a male gorilla (312). For the upper molar the corresponding values are about the same (*Gigantopithecus*: 378 against 130 in modern man); the gorilla molar is considerably smaller in this case (only 260 or one third). For the total height (crown and posterior root) of the third molar see Table 13. The argument that their extraordinary size forbids the attribution of *Gigantopithecus* teeth to man does not hold since the same argument could be advanced were they attributed to anthropoids. On the other hand, the new finds in Java (*Pithecanthropus robustus* and the *Meganthropus* mandible), which are unquestionably hominid forms, provide evidence that unusually large human types of monstrously massive skull and face bones did live there during the Middle Pleistocene. The existence of a fossil giant man in South China is, therefore, neither an impossibility nor even unique.

In addition to the size of the teeth, it is their height which seems the most divergent character. Strangely enough, it is just this "hypsidont" condition of the *Gigantopithecus* teeth which furnishes one of the proofs of their hominid character. As has been shown earlier (see Table 10), the height of these molars in proportion to the length or breadth is not greater but is even smaller than in modern man. Unworn upper human molars may be higher in relation to length and breadth than those of *Gigantopithecus*. The length-height index of *Gigantopithecus* M^1 is 66.3 compared with an average of 77.6 and maximum value of 85 in modern man; the height-breadth index of *Gigantopithecus* is 60.7–77.2 (according to whether the breadth at the base or the top of the crown is used) against an average of 72.8 and maximum values up to 80 in modern man. The upper molars of gorilla have similar proportions, but there is one essential difference: they are valid only if the height taken from the tips of the cones is considered as the actual height of the crown and the low crown level between the cones is neglected. In *Gigantopithecus*, however, there are no such differences, for the cusp blocks are set close together and the height is uniform (cf. Pl. 11a, c1; Pl. 12n). Another

feature may have some connection with the height; this is the incline of the lingual surface of the upper molar, already described. In modern man, however, this surface is vertically oriented, and the upper molars of gorilla may also have such a slope. As to fossil hominids, *Sinanthropus* does not differ from modern man in this regard, but the second and third right upper molars of *Pithecanthropus robustus* (Pl. 3d) display a similar condition.

A third possible argument against the human nature of the *Gigantopithecus* teeth is the special form of the third lower molar (Pl. 10, a1, c). In both specimens at hand the tooth is very long and its breadth sharply decreases toward its distal end; the trigonid breadth, therefore, considerably exceeds that of the talonid. As the same feature is found in the two *Gigantopithecus* individuals, it seems to be typical of *Gigantopithecus* and not an individual variation. We do not actually know how long the first and second lower molars were, but we can safely deduce from the lengths of the upper molar that these lower molars were shorter than the third one. In modern man the third lower molar is, as a rule, smaller, especially shorter, than the second and first ones. Adloff[1] writes:

The size of the molars decreases from the first to the third, in most cases, in both jaws. Nevertheless, the third lower molar never is reduced as much as the third upper molar, although it is usually smaller than the two preceding teeth. . . . Not too rarely, the third lower molar shows an elongation.

Adloff illustrated two of those cases (his figure 22 is copied here in Pl. 10, d1). Although he does not give a special description, it can be seen clearly from the figures that the "distal elongation" (talonid) is narrower than the mesial portion of the crown (trigonid). In other words, in modern man, if there is no general reduction of the third molar, it can and does show the same condition as the *Gigantopithecus* tooth: usually a broad trigonid and a narrow and well-developed talonid portion. That the third lower molar in modern man may exceed the first and second molars in length is proved by M. de Terra's figures. This author[2] gives the following maximum values for the length of the three modern human molars: M_1, 12.8 mm.; M_2, 12.5 mm.; M_3, 15.0 mm. In *Sinanthropus*

[1] Adloff, 1908. (Quotation translated from the original. F.W.)

[2] De Terra, M., 1905.

the third molar is especially reduced in length so that there is no essential difference between *Sinanthropus* and modern man in that respect. This is the more surprising because in the only *Pithecanthropus* mandible (Mandible B) and also the only one in which all three molars are preserved, the third molar is considerably longer than the first or second (Pl. 8d). The respective measurements are: M_1, 12.8 mm.; M_2, 13.6 mm.; M_3, 14.5 mm. In none of the dentitions of the known Neanderthalians in which the three molars are preserved is the third molar longer than the second, nor does it attract attention by a special development in length; on the contrary, all the Neanderthalian molars exhibit clear signs of reduction, as is the case in *Sinanthropus* and modern man.

The trigonid breadth is considerably greater than the talonid breadth in the two third molars of *Gigantopithecus*. As Table 11 shows, the trigonid index amounts to 75.3 in the left molar and to 81.8 in the right molar, while the corresponding figures of the talonid index are 65.6 and 70.8. The trigonid of the third molar of modern man is only slightly broader than the talonid, according to Gregory and Hellman's figures[1]; its average trigonid index is 90.7 and that of the talonid is 88.8; the minimum value of the former is 80 and of the latter 82.5. Fossil hominids show no essential differences. In *Sinanthropus* the average trigonid index is 96.6 and the average talonid index is 94.2, with the minimum values of 84.5 and 85.3, respectively. In *Pithecanthropus* (Mandible B) both indices are 86.2; talonid and trigonid have the same breadths. In the Neanderthalians, Gregory and Hellman[2] computed the indices in three cases, Heidelberg, Ehringsdorf, and Moustier. Their average is 92.0 and 87.7. The small difference between the trigonid and talonid breadth in all the hominids is, of course, due to the reduction of the size of the entire tooth which especially involves the length of the talonid and adjusts it, at the same time, to the breadth of the trigonid. In the rare cases in which the talonid of the third human molar is not reduced, as in the two "distally elongated" specimens depicted by Adloff[3] (see Pl. 10, d1), the trigonid index is distinctly higher than the talonid index. The measurements based on Adloff's figures show a

trigonid index of 80.6 and a talonid index of 74.2 for one tooth, while the respective figures for the other tooth are 75.2 and 87.7. Although the indices of these two third human molars are higher than those of the *Gigantopithecus* indices, they prove that even recent human M_3 can exhibit conditions similar to *Gigantopithecus*, if they preserve their original proportions. I shall revert to this point later.

This review shows that none of the most conspicuous features of the *Gigantopithecus* teeth, strange though they may appear at first sight, are incompatible with the character of human teeth. There now remains for discussion the question as to how far the special pattern of the *Gigantopithecus* teeth fits the hominid pattern. I begin with the lower molar.

1. THIRD LOWER MOLAR

In comparing the third lower molar of *Gigantopithecus* with that of modern man, one must keep in mind the fact that this tooth is more or less reduced in modern man, but that this is not true of the *Gigantopithecus* molar. For this reason the standard type for comparison must be the first or second molar of man. If the accessory internal tubercle between the metaconid and the entoconid is momentarily set aside, there are six well-developed cusps in *Gigantopithecus* (Pl. 10, b1): three on the buccal and three on the lingual side, namely, protoconid, hypoconid, and mesoconid; and metaconid, entoconid, and "tuberculum six," respectively. In modern man a reduction of the number of cusps has taken place in the second and third molars, especially, while the first molar has proved itself more resistant to this tendency. Therefore, there is great variability in the number of cusps. According to Zuckerkandl[4] five cusps are typical of the lower molars of recent man, but this number is found in only 11.5 per cent of all the molars. In 50 per cent the first molar has five cusps while the second and third have only four; and in 30.5 per cent the first and third molars have five cusps and the second molar four cusps. The typical five cusps are, buccal side: protoconid, hypoconid, and mesoconid; lingual side: metaconid and entoconid; the typical four cusps are protoconid and hypoconid, and metaconid and entoconid, respectively. The frequency of five or

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[1] Gregory and Hellman, 1926.
[2] Gregory and Hellman, 1926.
[3] Adloff, 1908.

[4] Zuckerkandl, 1902.

four cusps can also, to some degree, be deduced from the frequency of the "*Dryopithecus*" or "plus pattern," respectively. A "*Dryopithecus* pattern" suggests the presence of five cusps; the "plus pattern" coincides with the presence of four cusps.[1] According to Hellman the more primitive *Dryopithecus* pattern occurs in M_1 in 87 per cent of whites, 100 per cent of Mongols, and 99 per cent of West African Negroes. It is present in M_3 in 4 per cent of whites, and 20 per cent of Negroes. The more advanced "plus pattern" occurs in M_1 in 4 per cent of whites, but was never found in Mongols and Negroes, while it is found in the M_3 in 62 per cent of whites, 23 per cent of Mongols, and 17 per cent of Negroes.

The sixth cusp, "tuberculum six," is very characteristic of the *Sinanthropus* molars (Pl. 10, b2, b3, b4, e3) where, as in *Gigantopithecus*, it is situated closer to the lingual than to the buccal moiety of the molar.[2] In *Meganthropus*, in spite of the state of attrition exhibited, the first molar shows the presence of three cusps on the buccal side (Pl. 6, b3). The situation of the distal cusp indicates that there were also three cusps on the lingual side. In modern man the sixth cusp is very rare, according to M. de Terra,[3] and is almost restricted to the third molar. In Pl. 10, b5, b6, a second left lower molar of modern man (pre-Columbian American Indian) is depicted which shows "tuberculum six" as a distinct, wedge-like structural element between the mesoconid (at its buccal side) and the entoconid (at its lingual side) and separated from both by well-marked furrows.

In *Pithecanthropus* Mandible B, all three molars are worn and eroded, so that it is difficult to determine the exact number of their cusps (Pl. 8d). But there is no doubt that all three teeth had at least five cusps and probably also a "tuberculum six." In regard to the lower molars of the Neanderthalians, the "tuberculum six" is present in the M_2 of the Gibraltar child (Pl. 11, f1) and indicated also in the M_2 of the Mousterian youth.[4]

The relative size of the *Gigantopithecus* cusps corresponds to that of the cusps in the lower molars of modern man when due allowance is made for the reduction which has taken place

in the second and third molars which we have already noted. The sequence in the size of cusps of the third molar is more in accordance with that of *Sinanthropus* than with that of modern man, but the same conditions can be observed in the first molar of the latter (Pl. 10, b2). The metaconid is the largest and much the longest of the cusps; then comes the protoconid, with the hypoconid and the entoconid following in the order of their size. In *Gigantopithecus* the entoconid is little larger than the hypoconid, a condition sometimes to be found in *Sinanthropus*. As a rule, however, the entoconid is somewhat larger than the hypoconid in *Sinanthropus*, or the two cusps are of the same size. In *Gigantopithecus* as in *Sinanthropus*, the mesoconid is large, although smaller than the hypoconid, while "tuberculum six" is a small wedge-shaped insert between the mesoconid and the entoconid. However, since the furrow between the tubercle and the mesoconid is much more pronounced than the furrow which separates it from the entoconid, it appears rather as a wrinkle detached from the latter than as an independent cusp. Exactly the same condition may occur in *Sinanthropus*, as Pl. 10, b2, demonstrates. The second molar of the pre-Columbian American Indian (Pl. 10, b5, b6) shows the same size sequence as the *Gigantopithecus* molar. I am convinced that a great number of lower molars (first, second, and third) of modern man, showing the same arrangement and size of cusps, could be found were a search made for unerupted or slightly erupted molars in our collections of juvenile and adolescent skulls of American Indians and Asiatic peoples.

The tuberculum accessorium mediale internum (tam, Pl. 10, b1, c) is situated between the metaconid and entoconid in both lower *Gigantopithecus* molars; it occurs not only in orang-utan, as von Koenigswald's remark[5] suggests, but is also found in modern man, gorilla, and chimpanzee (cf. Table 14). According to M. de Terra[6] its presence has been noted in all three lower molars, but if his data are reliable, this tuberculum is much more frequent in M_3 than in the other two teeth. Adloff[7] gives the location of the accessory tubercle in man which I have copied in Pl. 10, d2. He refers to this tubercle in a controversy with Bolk concerning

[1] Hellman, 1928.
[2] Weidenreich, 1937a, 84.
[3] De Terra, M., 1905.
[4] Weidenreich, 1937a, 90–92.

[4] Von Koenigswald, 1935.
[5] De Terra, M., 1905.
[7] Adloff, 1916, Fig. 70.

the "dimer" theory. Bolk found it in siamang and gorilla; Adloff adds that it also occurs in orang-utan and "with relative frequency in man." The molars of fossil hominids, so far as they are on record, do not show a well-developed lingual tubercle. But in the *Sinanthro-*

TABLE 14

Frequency of the Occurrence of the Tuberculum Accessorium Mediale Internum in the Lower Molars of Anthropoids and Men
(in percentages)

Species	I. Anthropoids			Author
	M₁	M₂	M₃	
Gorilla	3	17	35	Remane (1921)
Chimpanzee	2 cases	10	7	Remane (1921)
Orang-utan ♂	12	36	18	Selenka (1898)
Orang-utan ♀	6	30	26	Selenka (1898)
Orang-utan ♀ and ♂	less than in chimpanzee			Remane (1921)

II. Recent Man				
Recent European	1.48	1.02	2.55	
Roman graves	—	—	3.7	
Non-Negro Africans	6.25	2.7	7.44	
Egyptian (ancient)	3.2	—	—	M. de Terra (1905)
Chinese	—	12	8	
Malayan	—	—	4.3	
Burman	9	—	—	
Papuan	—	—	20	
Australian	6.25	—	—	

pus M₁, No. 36 (Pl. 10, b3), and M₂, No. 44 (Pl. 10, b4), the distal portions of the metaconids appear as fairly independent wrinkles which might almost pass as real tubercles although they are not so completely isolated as the *Gigantopithecus* tubercle. The lingual accessory tubercle is not, therefore, a specific feature of the *Gigantopithecus* tooth which is incompatible with its hominid character.

The character of the main furrows which separate the cusps neither offers any clue to the nature of the tooth nor is inconsistent with a human molar. The course and distribution of the furrows are the same as in all molars of higher primates, whether anthropoids or hominids, which have five or six cusps. They have the typical *Dryopithecus* pattern, diverging from it only in respect to the lingual accessory

tubercle. The lingual section of the transverse furrow which separates the metaconid from the entoconid is not single as in normal cases where no tubercle has developed, but divides into two branches.

We now have left for discussion the question as to why this lower molar of *Gigantopithecus* is that of a hominid and not of an anthropoid. All the features so far described are found in anthropoids and hominids alike. They do not make it impossible to attribute the tooth to man, but they are not positive criteria of its true nature. In the introductory section dealing with *Gigantopithecus*, I stated why it is insufficient to study only the number and arrangement of the cusps, when identifying a tooth as to type. I have shown that the *form* of the cusps and especially the character of their wrinkles are decisive factors in making a choice, and I have analyzed the principles dominant in man and the great apes. The essential peculiarity of the *Gigantopithecus* molars is one which I have called, when describing the human tooth, the "block pattern" of their main cusps. All rise from the base more like cubes than cones. They develop tips high on the cusps so that the "blocks" fit tightly, and are intersected by deep narrow fissures which retain their character up to the occlusal surface (cf. Pl. 11a, c). Even the accessory cusps, the "tubercle six," and the lingual tubercle have this block-like character. A slight attrition, only sufficient to remove the tips, does not effect much change in the original surface. The area of each cusp appears as a plane—a slightly undulated plateau—rather than as a peak with steep slopes (cf. Pl. 10, a1, a2, a4). The surface wrinkles are not ridges with sharp contours but broad, rounded folds, with few secondary indentations. When the *Gigantopithecus* molars are compared with those of modern man (Pl. 10, b1, b6), the similarity of their patterns is striking. That there is no complete conformity goes without saying, for no two hominid molars of the same type agree with each other in the minor details of their patterns (cf. the three *Sinanthropus* molars, (Pl. 10, b2, b3, b4). The decisive point is their agreement in structural principle.

At first glance it would seem that *Gigantopithecus* conforms to the pattern of modern man more closely than to that of *Sinanthropus*. The occlusal surface of *Sinanthropus* (Pl. 10, b2, b3, b4) appears more rugged than that of

Gigantopithecus; whether or not this is an actual condition is a matter impossible to decide with certainty. The greater smoothness in the latter may be due to greater attrition. However, I believe that the *Gigantopithecus* teeth are actually less wrinkled than the *Sinanthropus* teeth and, in that respect, more nearly approach the teeth of modern man than do those of *Sinanthropus.* I shall elaborate this point later. Considering the great variability of the wrinkle system, it seems impossible to single out a special type for identification. Nevertheless, it is surprising how often the wrinkle of the *Gigantopithecus* metaconid which I have designated as the "deflecting wrinkle" (dw) recurs in the molars of fossil and recent man. It is very distinct in the American Indian tooth in Pl. 10, b5, b6; it is apparent in all four of the *Sinanthropus* molars figured (Pl. 10, b2, b3, b4); and it is very clear in the M_2 of *Pithecanthropus* Mandible B (Pl. 8d), in spite of the wear and erosion of those teeth.

The human character of the *Gigantopithecus* molar can also be proved *per exclusionem.* In Pl. 10, a1, a2, a3, a4, I have illustrated the lower molars of gorilla, orang-utan, and chimpanzee to show the characteristic traits of their pattern. Only completely unworn teeth or, in the case of the fossil orang (a3), very slightly worn teeth have been selected, in order to have additional minor characters for comparison. A superficial glance at the teeth of gorilla (a2) and chimpanzee (a4) reveals that they do not resemble the special pattern of *Gigantopithecus* and certainly they have no closer resemblance to *Gigantopithecus* than has modern man (b6). Their cusps are high, isolated, and pointed cones, with deep valleys between them; the wrinkles form steep sharp crests between them, as has already been stated. In the case of the gorilla (a2) the lingual accessory tubercle (tam) has developed, but it is like an isolated thickened portion of the marginal border between the metaconid and entoconid. This is certainly a very different picture from that represented by *Gigantopithecus* (b1) and the hominids (b2–b4, d2). The only one of the recent great apes which approaches closer to *Gigantopithecus* is the orang-utan. In Pl. 10, a3, I illustrate the third, right, slightly worn molar of a fossil orang-utan excavated from a cave in Kwangsi (South China). The locality in which the tooth was found and its condition indicate that the

Gigantopithecus molar came from a similar site, and was contemporaneous with these orang-utans. The only difference in pattern between this fossil orang-utan tooth and that of a recent one is that the tips of the cusps are more pronounced and the wrinkles are less abundant in the former. The fossil orang-utan tooth resembles the *Gigantopithecus* molar in the form, number, arrangement, and height of the cusps as well as in their tightly set condition. In the center and on the lingual side is a similar "disturbance" in the wrinkle system; the wrinkles separate at their ends in such a way as to produce approximately a typical accessory tubercle (tam). On the other hand, the wrinkles are much less numerous in *Gigantopithecus,* and the marginal border, marked by the set of the tips of all the cusps, is much less pronounced.

One other remarkable peculiarity distinguishes the *Gigantopithecus* molar from those of the great apes and brings it closer to man. This is the absence of a cingulum, or a special formation deriving from it, which is well developed in the gorilla (Pl. 10, a2; Pl. 11, c1), while in the chimpanzee the presence of the same structure is indicated only by the way in which the conical surfaces of the individual cusps are carved out of the buccal side of the crown (Pl. 11, c3). In *Gigantopithecus* the upper half of both the buccal and lingual sides of the crown is partitioned into blocks by continuations of the transverse furrows of the occlusal surface, and only the very slight tapering of the blocks toward the occlusal surface suggests the original conical character of the cusps. A similar tapering is found in the molars of modern man and is indicated in *Sinanthropus,* although many molars show special differentiations which are to be considered as relics of a cingulum (c, Pl. 11d). The three molars of the *Pithecanthropus* Mandible B (Fig. 8) are like those of modern man in this respect.

The root of the *Gigantopithecus* molar (Pl. 10h; Pl. 11a), that is, the posterior root, has no feature which does not fit into a human pattern. Of course, consideration must be given to the tendency toward reduction of the root in the molars of all hominids, whether fossil or recent. But where the roots are not fused, the posterior branch often exhibits the same general shape and some of the special features of *Gigantopithecus.*

2. UPPER MOLAR

In discussing the human character of the *Gigantopithecus* teeth, I dwelt mainly on the lower molar because it is the least worn, and, in general, lower molars display the characteristics of the type more clearly than the upper molars. On the other hand, in the upper molar of *Gigantopithecus*, the form of the crown, the size, the arrangement of the cusps, and their relation to each other so strongly resemble the human pattern that the description of the pattern of the human upper molar in Mummery's text book could be applied to *Gigantopithecus* without changing a word (see p. 76). If one followed Mummery's description the only essential difference between

TABLE 15

FREQUENCY OF THE OCCURRENCE OF THE OBLIQUE CREST IN UPPER MOLARS OF RECENT MAN (IN PERCENTAGES)[a]

Races	M[1]	M[2]	M[3]
Modern European	49.8	12	17.3
Ancient European	26	0	20
Africans	32.7	23	0
Papuan	79.2	12	0
Other non-European races	50	0	0

[a] After Vram, 1897.

modern man and *Gigantopithecus* would be the existence of an oblique crest between metacone and protocone in the human molar and its absence in *Gigantopithecus*. In judging the *Gigantopithecus* pattern, allowance should be made for the possibility that such a crest was originally present, but was lost through attrition; however, examination does not lend any support to such a supposition. The tooth has, undoubtedly, been subjected to attrition, but not enough to show clearly any wear of the metacone. The attrition has been restricted to the lingual side, the protocone and the hypocone. The area of the metacone is not a smooth plane, as it would be if it were worn, but is distally undulated; it has the "clover-leaf" pattern to which I have already referred (tf, Pl. 12, a2). If there had been a crest its worn base would still be recognizable, but there is none. The protocone, too, although its area is smoothed, offers no evidence that the base ever carried a crest connecting it with metacone. The cusps are separated from each

other by a very pronounced furrow which is not so deep as those separating the metacone from the paracone and hypocone, but deeper than those between protocone and paracone and protocone and hypocone.

Topinard[1] and Mummery[2] believed the oblique crest occurred regularly, but this belief is not supported by the statistics in Table 15. Although the figures obtained by Vram[3] are of doubtful reliability, they prove that even in the first molar, which has a strong tendency to retain primitive features, the oblique crest is absent in from two thirds to one half of all the cases, if the Papuans are excluded. A closer connection between the metacone and protocone in human teeth can be perceived if the cusps are worn to their bases. In unerupted or just erupted human teeth there is never any direct connection between the two cusps which could be designated as "an oblique crest" in the sense that term is used in describing the occlusal pattern of anthropoid molars. In the two human teeth, one (Pl. 12k) the immature first left molar of a prehistoric Chinese child, and the other (Pl. 12b) a just erupted second right molar of a Siamese child (A.M.N.H. No. 2448), the metacone and protocone are inclined toward each other, but there is no oblique connecting crest.

The special pattern of the occlusal surface of the *Gigantopithecus* molar (Pl. 12a) has been described above. It differs only slightly from that of modern man (Pl. 12b, k); the cusps rise more steeply from their bases and the tips are more pronounced in the latter than in *Gigantopithecus*. In both specimens of modern man illustrated the wrinkle system is the same as it is in *Gigantopithecus*. The "flower-bud pattern" of the paracone (fb) is very distinct, and there is also great conformity in the appearance of the protocone. Considering this similarity it is surprising that the occlusal surface of the unworn *Sinanthropus* molars (Pl. 12c, g) is so much more wrinkled, that these teeth appear more removed from the *Gigantopithecus* pattern than do the teeth of modern man.[4] On the other hand, there is great similarity between

[1] Topinard, 1892.
[2] Mummery, 1924.
[3] Vram, 1898.
[4] For the peculiarities of the *Sinanthropus* pattern, the reader is referred to my paper on the *Sinanthropus* dentition, 1937a.

the molars of *Pithecanthropus robustus* and the *Gigantopithecus* molars. Although the former are fairly worn, the "flower-bud pattern" in the right M¹ and M³ is very distinct (fb, Pl. 12i).

When compared with the upper molars of the three great apes, the *Gigantopithecus* upper molar exhibits the same basic differences as the lower. In the gorilla the cones are much higher (Pl. 12d), the slopes steeper, and the edges and wrinkles sharper. The tips are more pointed and are located above the center of the base of the cones. Here we have a well-developed oblique crest (co) which appears as an "arête" extending from the top of the metacone to the top of the protocone. Although the cusps are separated by a fissure, the crest extends from one to the other. There is no difference between chimpanzee and gorilla in all these structures; they are merely more delicate in the former, exactly as is the case in the lower molar (Pl. 10, a2, a4). For this reason I refrained from illustrating examples of the chimpanzee molars in special figures. Instead I have shown the upper molar of *Dryopithecus germanicus* (Melchingen) in Pl. 12f. The difference in pattern between this tooth and that of a chimpanzee is minimal when compared with other anthropoid or hominid molars. I shall return to this *Dryopithecus* tooth later. The upper molar of *Gigantopithecus* is more like that of fossil orang-utan (Pl. 12, e1) than like those of gorilla or chimpanzee. The cusps in orang-utan are lower and the edges and wrinkles much more rounded than in the latter. In the recent orang-utan (Pl. 12, e2) the wrinkle system has reached such a high degree of development that the individuality of the

cusps, so characteristic of *Gigantopithecus* and modern man, has been almost completely lost. Yet the fossil orang-utan molar (e1) shows fewer wrinkles, so that the tooth looks more like that of *Sinanthropus*, but modern man undoubtedly resembles the *Gigantopithecus* tooth even more closely than does that of the fossil orang-utan.

As is the case in the lower molar, not even the vestige of a cingulum is left in the upper molar of *Gigantopithecus*. In this respect also, *Gigantopithecus* comes closer to modern man than either the recent great apes or *Sinanthropus*. In *Sinanthropus* the buccal side of the paracone shows slight curved indentations which, to a certain extent, recall the original conical form of this cone.[1] Such indentations are completely lacking in *Gigantopithecus*. In the great apes the cingulum, or at least the structures which can be traced back to the cingulum, are very pronounced on the buccal and lingual sides of the upper molars—more pronounced in gorilla and chimpanzee than in orang-utan. It is especially the pronouncedly conical form of the cusps with deep indentations between them which determines the character of the relief on the sides. In *Gigantopithecus*, as in modern man, the cusps are close together and have a block-like form (Pl. 12n) which has already been described.

What is left of the root of the *Gigantopithecus* upper molar allows only one conclusion, that there was a single root on the lingual and two roots on the buccal side. This arrangement is characteristic of man as well as of anthropoids and furnishes no further clue to the nature of the molar.

D. *GIGANTOPITHECUS* AND THE FOSSIL ANTHROPOIDS

The comparison of the particular pattern of the upper molar with the corresponding teeth of anthropoids and hominids corroborates the results already obtained from the study of the lower molar: *Gigantopithecus is not an anthropoid but a typical hominid*. Although this is a fact beyond possibility of objection, we must still see how the *Gigantopithecus* teeth agree or disagree with those of the fossil anthropoids, as represented by *Sivapithecus, Dryopithecus*,

and related forms on the one hand, and the Australopithecinae on the other. I do not intend to compare each feature peculiar to these forms and separately with those of *Gigantopithecus*. We need only give our attention to the main structures which determine the characters of the special types and distinguish them from hominids and recent anthropoids. For all other details of the *Dryopithecus* group the

[1] Weidenreich, 1937a.

reader is referred to Branco,[1] Abel,[2] Pilgrim,[3] Remane,[4] Gregory and Hellman,[5] Gregory, Hellman, and Lewis[6]; for the Australopithecinae to Dart,[7] Gregory and Hellman,[8] and Broom.[9]

Let us begin with the lower molar. In 1935, von Koenigswald called attention to the great similarity between the third lower molar of *Gigantopithecus* and the third lower molar of *Sivapithecus middlemissi*, described by Pilgrim in 1927 and illustrated in his Fig. 7 and 7a. This tooth is much smaller than the *Gigantopithecus* tooth, for it actually measures only 14.4 mm. in length and 13.2 mm. in breadth compared with the corresponding 22.3 mm. and 17.0 mm. for these dimensions in *Gigantopithecus*. But its shape is the same; the trigonid is very broad and the talonid decreases in breadth toward the distal end. Unfortunately, the *Sivapithecus* tooth is badly worn. The number of cusps (three on either side) seems to be the same as in the *Gigantopithecus* molar, but they are so worn that there is no possibility of describing the form and character of the cusps and wrinkles. Another third lower molar from the Siwaliks has been named *Dryopithecus giganteus* by Pilgrim[10] because of its size. This tooth (Pl. 10g), with a length of 19.1 mm. and a breadth of 15.3 mm., comes much closer to *Gigantopithecus* than does *Sivapithecus middlemissi*. Its form is the same as that of *Gigantopithecus*—broad trigonid portion and gradually narrowing talonid. (For trigonid and talonid index see Table 11.) The tooth is excellently preserved and virtually unworn. There are three cusps at the buccal side and three on the lingual, but "tubercle six" is very small, and there is no tubercle accessorium mediale internum. These differences, however, are not decisive. The really decisive peculiarities are the form of the cusps and the character of the wrinkles.[11] The cusps are

typical cones, not so high or pointed as in gorilla but with the tips situated vertically over the center of their bases. For this reason the buccal surface inclines slightly outward. The cusps, especially the metaconid and entoconid, have no block character, but are individual entities separated from each other by broad valleys. All this resembles so closely the condition of the recent gorilla molar (Pl. 10, a2) that the tooth can be classified as a gorilloid type. In any case it is quite different from *Gigantopithecus*. The lower third molar of *Sivapithecus* (?) cf. *darwini* described by Gregory, Hellman, and Lewis[12] has the same form as the *Gigantopithecus* molar, although it is much smaller: length, 13 mm.; breadth, 12 mm. The pattern of the occlusal surface is very similar to that of *Gigantopithecus*, even in the suggestion of an inner accessory tubercle. But the form of the cusps, especially those on the buccal side, is like that of *Dryopithecus giganteus*, and there are broad valleys between the cusps. *Dryopithecus darwini* (Pl. 11, g2)[13] belongs to the same category as far as the pattern is concerned. Abel considers this type as "the most human-like primate known thus far."[14] This explains its close resemblance to the *Gigantopithecus* molar, although it differs from this to the same degree that it differs from a hominid tooth. The same holds true for the third lower molars of *Dryopithecus frickae* (Pl. 11, g1), of *Sugrivapithecus gregoryi*,[15] *Dryopithecus punjabicus*,[16] *Dryopithecus chinjiensis*,[17] *Bramapithecus punjabicus*,[18] *Sivapithecus indicus*.[19] The general pattern of some of the *Dryopithecus* teeth from the Lower Pliocene of Germany, those named *D. rhenanus*[20] and *D. germanicus*,[21] is also similar to that of *Gigantopithecus*, but Gregory[22] and Remane[23]

[1] Branco, 1898.
[2] Abel, 1902, 1931.
[3] Pilgrim, 1915–1916, 1927.
[4] Remane, 1921.
[5] Gregory and Hellman, 1926.
[6] Gregory, Hellman, and Lewis, 1938.
[7] Dart, 1934.
[8] Gregory and Hellman, 1939a, 1939b.
[9] Broom, 1937, 1938, 1939a, 1939b.
[10] Pilgrim, 1915–1916.
[11] Unfortunately, the photograph of the cast which is

painted to reproduce the dark red color of the original (Pl. 10g) does not show these features clearly.
[12] Gregory, Hellman, and Lewis, 1938, Pl. 3, Figs. 4a and A.
[13] Cf. also Abel, 1902, Fig. 3.
[14] Abel, 1902.
[15] Gregory, Hellman, and Lewis, 1938, Pl. 3, Fig. 8a.
[16] Pilgrim, 1915–1916, Pl. 1, Fig. 5.
[17] Pilgrim, 1927, Fig. 4.
[18] Pilgrim, 1927, Pl. 3, Fig. 9a.
[19] Pilgrim, 1927, Pl. 3, Fig. 7.
[20] Abel, 1902.
[21] Abel, 1931.
[22] Gregory, 1916.
[23] Remane, 1921.

agree that these also have many characteristics in common with the teeth of the modern chimpanzee (cf. Pl. 12f). As a matter of fact, the buccal cusps of the lower molars of *Dryopithecus*, including the specimen from Trochtelfingen which has a distinct accessory tuberculum internum,[1] are pronouncedly conical. There is also a typical fovea posterior. Both of these features are lacking in *Gigantopithecus* and other hominids. Therefore the lower molar of *Gigantopithecus* cannot be classified as belonging to any of the known fossil anthropoid forms, nor can it be regarded as a new type of those forms. It differs from them to the same degree as does the lower molar of any hominid. The orang-utan is the only anthropoid which has a pattern bearing some resemblance to *Gigantopithecus* and it is not the living but the fossil orang-utan from South China which approaches the pattern most closely. It is interesting that none of the fossil primate types, so far known from India, approach the tooth pattern of the orang-utan.

When their unworn condition makes comparison with the *Gigantopithecus* molar possible, the lower molars of the Australopithecinae show agreement in general pattern. The first molar of *Australopithecus africanus* Dart (Pl. 11e; Pl. 12h), the third right lower molar of *Plesianthropus transvaalensis*[2] and *Paranthropus robustus* (Pl. 11, g3)[3] agree with *Gigantopithecus* in all those features that are common characteristics of anthropoids and hominids. These include the general pattern of the occlusal surface and the number and arrangement of the cusps. In all the Australopithecinae molars the "tuberculum six" is well developed, and there are three cusps on the buccal side and three on the lingual side. However, it cannot be considered a mere individual or accidental variation that in each of the three Australopithecinae types mentioned, the metaconid is not only of the same size as the protoconid, but does not extend farther in distal direction than does the latter (Pl. 11e). This is in sharp contrast to *Gigantopithecus* (Pl. 10, a1) and *Sinanthropus* (Pl. 10, 2–4) where the metaconid is considerably larger than the protoconid and extends distally by means of the "deflect-

ing wrinkle" (dw) to join the hypoconid. In the *Australopithecus* specimens, contact between the metaconid and the hypoconid is made by the hypoconid which extends beyond the mid line toward the metaconid (Pl. 11e). This peculiar feature did not escape the attention of Gregory and Hellman[4] in their description of the *Plesianthropus transvaalensis* pattern, but they attach greater importance to the change of the "*Dryopithecus* pattern" than to that of the cusps. They conclude:

. . . We are witnessing in this progressive anthropoid the origin of the plus pattern from the Y (*Dryopithecus*) pattern in the same way in which it is now occurring among modern men.

Similar conditions are also found in the *Dryopithecus* group. The contact between the metaconid and hypoconid by the prolongation of the latter and its extension beyond the mid line toward the metaconid is distinct in *Dryopithecus darwini* Abel (Pl. 11, g2), *Dryopithecus germanicus* of Melchingen,[5] and *Dryopithecus frickae* (Pl. 11, g1).

In addition to these peculiarities, there are other features which prove that the Australopithecinae molars are closer to the anthropoids than to *Gigantopithecus*. In *Australopithecus* (Pl. 11e) the cusps of the buccal side have distinctly conical surfaces and exhibit relics of cingulum and even of styles. The same is true of *Plesianthropus* and *Paranthropus* (Pl. 11, g3). These structures are completely absent in *Gigantopithecus* (Pl. 11, a1), although they are indicated in *Sinanthropus* (Pl. 11d). The cusps in *Paranthropus* are also relatively high cones with centrally located, pointed tips, and steep slopes covered with many sharply edged wrinkles. In other words, they are of a gorilla and not of a hominid type as are the cusps in *Gigantopithecus*; while *Australopithecus* comes closer to *Gigantopithecus* and the hominids in this respect.

This analysis demonstrates that the lower molar of *Gigantopithecus* has no stronger resemblance to the molars of fossil anthropoids than it has to recent ones and certainly has no greater resemblance to either than it has to man.

The comparison of the upper molar of *Gigantopithecus* with the *Dryopithecus* group

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[1] Gregory and Hellman, 1926, Fig. 6D; Abel, 1931, Fig. 88.
[2] Gregory and Hellman, 1939a, Fig. 13.
[3] Gregory and Hellman, 1939a, Fig. 12.

[4] Gregory and Hellman, 1939a.
[5] Abel, 1902, Fig. 2.

and the Australopithecinae can be brief, for few specimens are preserved and, in addition, our identification of the individual character- istics of the pattern of the lower molar also holds good for the upper one. None of the *Dryo- pithecus* or *Sivapithecus* types, *D. chinjiensis*,[1] *D. punjabiensis*,[2] *S. orientalis*,[3] *S. indicus*,[4] pos- sesses the block character of the *Gigantopithecus* cusps; all are high cones with more or less pronounced tips and sharp crests revealing the gorilla type of pattern. In all of them there is a well-developed oblique crest uniting meta- cone and protocone with only a superficial narrow furrow between them. All of them, except *Sivapithecus orientalis* and *S. indicus*, have a cingulum, or relics of it, on the buccal or lingual side. *Dryopithecus germanicus* of Melchingen (Pl. 12f) is absolutely like a recent chimpanzee. Of the group, *Palaeosimia rugo- sidens*[5] is the only type which approaches the orang-utan (but not *Gigantopithecus*) to some extent. Although this form has an abundance of well-developed wrinkles, the cusps are high and the crests steep and sharp.

As far as the Australopithecinae are con- cerned, the first molar of *Australopithecus* differs from *Gigantopithecus* in the same man- ner as the lower molar. The cusps are more conical, show no block character, and there are also some distinct traces of the cingulum. Furthermore, *Australopithecus* has a kind of oblique crest with the same deviation from the usual pattern as has been described for *Sinan- thropus*. This crest (Pl. 12h), descending from the metacone, continues beyond the mesial- distal fissure into an accessory tubercle which is inserted between protocone and hypocone,

apparently representing the separated distal portion of the protocone. Such a feature is completely lacking in *Gigantopithecus*. The molars of *Paranthropus robustus*, except for one, are more worn than the *Gigantopithecus* molar, but enough is left of the special pattern to enable one to pass judgment on similarities and dissimilarities. The best-preserved of the *Paranthropus* molars, the right third lower (Pl. 11, g3), differs from the *Gigantopithecus* molar in having a small metacone and a large protocone. The upper molars, more worn but with some details of the pattern still left, show a crista obliqua, so we must conclude that this feature is characteristic of *Paranthropus*. The right upper molars of *Plesianthropus transva- alensis* depicted by Gregory and Hellman[6] have a special pattern of their own which is quite different from that of *Gigantopithecus*. A broad ridge on the distal margin is much crenated; in addition, metacone and hypocone, while closely connected, have each disintegrated into several elements. In this case also the protocone is much larger than the other cusps.

What has been said about the lower molar of *Gigantopithecus* is also true of the upper molar. There is no close connection between that tooth and similar teeth of the *Dryopithecus* or Australopithecinae groups. The upper molar of *Gigantopithecus* does not resemble any representative of the fossil anthropoids more than does fossil or recent man. The *Giganto- pithecus* teeth are undoubtedly hominid teeth. Their patterns agree with those of fossil or recent anthropoids only to the same extent and in the same way that the teeth of fossil and recent man agree.

E. RELATIONSHIP BETWEEN *GIGANTOPITHECUS* AND OTHER HOMINIDS

The *Gigantopithecus* teeth, as shown in the previous section, combine primitive and ad- vanced characters in such a way that a special place among the hominids must be reserved for the *Gigantopithecus* type.

If we consider the *Sinanthropus* teeth as the most primitive hominid teeth so far known and use their pattern as a standard against which to check primitive and advanced features, then the *Gigantopithecus* molars are seen to be more primitive in several characters:

1. The third lower molar does not indicate any reduction in size or shape of either crown or root as is the case with *Sinanthropus*. Most lower third molars of *Sinanthropus* show con-

[1] Pilgrim, 1915–1916, Pl. 1, Fig. 7.
[2] Pilgrim, 1915–1916, Pl. 3, Figs. 11, 12.
[3] Pilgrim, 1927, Fig. 4.
[4] Pilgrim, 1927, Fig. 5; Gregory, Hellman, and Lewis, 1938, Pl. 5, B, C, and Pl. 7, F.
[5] Pilgrim, 1915–1916, Pl. 2, Fig. 9.

[6] Gregory and Hellman, 1939a, Fig. 10.

siderable reduction in the size of the crown, particularly in the inferior-posterior direction, as well as a distinct tendency toward fusion of the two roots. This does not occur in *Gigantopithecus*.

2. The trigonid of the *Gigantopithecus* molars is considerably broader than the talonid; the trigonid index is 78.5 (average of both teeth) and the talonid index is 68.2 (average) compared with an average of 96.6 and 94.2, respectively, for *Sinanthropus* (see Table 11). In modern man the average trigonid index is 90.7, and the talonid index is 88.8. The trigonid index of *Gigantopithecus* is almost 10 units greater than the talonid index, while the difference is only 2.4 units in *Sinanthropus* and about 2 units in modern man.

3. There is no reduction in the number of cusps in the *Gigantopithecus* molar, as is often true in the third molar of *Sinanthropus* and of modern man. However, in evaluating this character, we must remember that in third molars, even in modern man, the number of cusps has a great tendency to vary; they may diminish or increase in number.

4. The lingual surface of the upper molar declines from the neck toward the occlusal surface, forming an angle of 68° with the horizontal palate. Nothing of this kind is found in *Sinanthropus* teeth where the surfaces are vertically oriented to that horizontal as are those of modern man.

On the other hand, some features of the *Gigantopithecus* molars indicate a more advanced condition when compared with *Sinanthropus*:

1. The absence of a cingulum or any related structures which could be traced back to it. *Sinanthropus* exhibits different forms of these structures. Those most frequently found are curved elevations marked by curved indentations (Pl. 11d). They may be interpreted as the remnants of the originally conical cusps which rose from the base of a crown girdled with a cingulum.

2. The wrinkles are much less numerous in *Gigantopithecus* than in *Sinanthropus* where the occlusal surface of both upper and lower molars is characterized by an abundance of coarse and rounded wrinkles.

3. The oblique crest which, in the upper molar, unites metacone and protocone is absent in *Gigantopithecus*. This crest occurs occa-

sionally in *Sinanthropus*, but is of a different character—a point elaborated earlier. It is missing in more than half the cases of modern man.

For all these reasons, *Gigantopithecus* cannot be considered merely as a giant *Sinanthropus*. It is related to *Sinanthropus*, but represents a different form. On the other hand, certain features bring *Gigantopithecus* nearer to *Pithecanthropus* in so far as the latter is represented by the teeth of Mandible B and the maxilla of *Pithecanthropus robustus*:

1. In Mandible B the third lower molar is not reduced, but is considerably larger than the two preceding molars (Pl. 8d).

2. There is no cingulum, not even a trace of one, in either the upper or lower molars of *Pithecanthropus* (Pl. 8d; Pl. 3d).

3. The wrinkles are less developed in *Pithecanthropus* than in *Sinanthropus*.

4. The lingual surface of the second upper molar inclines as does that of *Gigantopithecus* (Pl. 3d). The fact that the "deflecting wrinkle" of the *Gigantopithecus* metaconid is very distinct in the second molar of Mandible B (Pl. 8d) and that the "flower-bud" pattern of the *Gigantopithecus* paracone is clearly discernible in the first and third upper molars of *Pithecanthropus robustus* (Pl. 3d) cannot be used as evidence of identity or immediate relationship. In both cases it suggests the general hominid character of the teeth.

On the other hand, the *Pithecanthropus* teeth have three peculiarities quite different from those of the *Gigantopithecus* molars:

1. The trigonid of the third lower molar of Mandible B is not larger than the talonid, but is equal in breadth; the trigonid and talonid index is 86.2 against 78.5 and 68.2, respectively, in *Gigantopithecus*.

2. The oblique crest is well developed in the second upper molar of *Pithecanthropus robustus*.

3. The *Pithecanthropus* teeth are not essentially larger than the *Sinanthropus* teeth, and both are much smaller than the teeth of *Gigantopithecus*.

When compared with the first lower molar of *Meganthropus*, the only tooth of this type available, there is no particular agreement in this respect to *Gigantopithecus*. The *Meganthropus* tooth is much more worn than the *Gigantopithecus* molar, and, therefore, very little of the occlusal pattern is left; nevertheless, there are

two characteristic differences. The metaconid of *Meganthropus* is about the same size as the protoconid; above all, it is not larger, as is the case in *Gigantopithecus*. On the other hand, the buccal surface of the *Meganthropus* tooth, particularly the outside of the protoconid, shows distinct traces of a cingulum differentiation (Pl. 6, b1, b3), which is typical of *Sinanthropus*, but completely lacking in the third molar of *Gigantopithecus*. As to size, the *Meganthropus* molar is much larger than the corresponding

Pithecanthropus, and *Meganthropus*), much depends on the evaluation of the differences in the tooth pattern as stated above. *Sinanthropus*, for instance, still shows distinct cingulum relics, but its third lower molar is greatly reduced in length, while in *Gigantopithecus* and *Pithecanthropus* (Mandible B) the third molar is very long, the longest of the three in *Pithecanthropus* and probably also in *Gigantopithecus*, yet no relic of a cingulum is left. On the other hand, the trigonid is much broader than the talonid

TABLE 16

CALCULATIONS (C.) OF THE SIZE OF THE MISSING TEETH OF *Gigantopithecus* AND *Meganthropus* (IN MILLIMETERS)

Lower Teeth	*Giganto-pithecus*	*Megan-thropus*	*Pithecan-thropus* Mandible B	*Sinanthropus* Mandibles A, G, and K Average	Heidel-berg	Modern Man Average	Gorilla ♂	Orang-utan ♂	Chim-panzee ♂
Length of M_1	19 c.	15	12.5	12.7	11.2	11.2	—	—	—
Length of M_2	11.8 c.	15.6 c.	13	12.4	12.8	11	—	—	—
Length of M_3	22.1	18 c.	14.5	11.6	12.7	10.8	—	—	—
Length of the molar row	60.9 c.	48.6 c.	40	36.7	36	33	51	47	33

Upper Teeth	*Giganto-pithecus*	*Megan-thropus*	*Pithecan-thropus robustus*	*Sinanthropus* Average of Maximum Val.	Modern Man Average	Gorilla ♂			
Length of M^1	18.7	—	12.2	11.9	10.8	(15.0)			
Length of M^2	20.8 c.	—	13.6	10.9	10	(16.2)			
Length of M^3	16.5 c.	—	10.8	9.4	9.7	(14.9)			
Length of the molar row	56 c.	44 c.	36.6	32.2	30.5	46.1 47.5 av.			

teeth of *Pithecanthropus* and *Sinanthropus*. The respective rectangles are as follows: *Meganthropus* M_1, 202.5; *Sinanthropus* M_1 (maximum), 171; *Pithecanthropus* (Mandible B) M_1, 162; M_3, 181; *Gigantopithecus* M_3, 335 and 370 (Figs. 10, 24, 25; Tables 7 and 10). We do not know the size of the first lower molar of *Gigantopithecus*, but its dimensions can be calculated on the basis of the difference between the size of M_1 and M_3 in *Pithecanthropus* Mandible B (cf. Table 16). Provided the ratio of difference is the same in both cases, the rectangle of *Gigantopithecus* M_1 would range from 330 to 343; or the *Gigantopithecus* M_1 would be 61 per cent larger than the *Meganthropus* M_1.

In passing judgment on the closer or remoter relationships between the four hominid types under discussion (*Gigantopithecus, Sinanthropus,*

in *Gigantopithecus*, while they are of equal breadth in *Pithecanthropus*. It might be deduced from these facts that *Gigantopithecus* is more closely related to *Pithecanthropus* than to *Sinanthropus*. But which of these is the more primitive type depends entirely on whether the loss of the cingulum or the reduction in size and proportion of the third molar is regarded as the more completely removed from the original line. Hrdlička[1] states, with regard to the size and length of the molars of hominids:

It is safe to regard as primitive or phylogenetically inferior a tooth that is absolutely large so as to give a low crown index.... In early man the ancient conditions of the molars progressing in size from before backwards is still more or less in evidence in

[1] Hrdlička, 1924.

the older forms, disappearing more and more as recent times are approached.

Comparison with the anthropoids is of no great help in this decision. The cingulum is best developed in gorilla, less in chimpanzee, and least in orang-utan, but the third molar indicates a reduction in chimpanzee, though not in gorilla or orang-utan.

In any case, it must be remembered that there is great variation in all the features considered as characteristic. The oblique crest of the upper molars which is typical of the anthropoids, for instance, was not developed in the *Gigantopithecus* molar; it is, however, present in *Pithecanthropus robustus*. In *Sinanthropus* this crest shows divergence from the usual appearance in that there is no connection with the tip of the protocone, but with a separated, special, distal portion of it. If typically developed, it has the aspect of a small, accessory, lingual tubercle, inserted between protocone and hypocone (Pl. 12c), and is exactly this in *Australopithecus* (Pl. 12h). Even in modern man the oblique crest may be either present or absent (cf. Table 15).

In this analysis no mention has been made of the accessory internal tubercle of the lower molars of *Gigantopithecus*. That this tubercle is not merely an individual variation is proved by the fact that both lower molars, the worn right (Pl. 10c) and the more intact left one (Pl. 10, a1), exhibit this peculiarity. As the two teeth obviously belong to two different individuals, the presence of this tubercle in both molars must very likely be regarded as part of the regular structure of the third molar and not, as in modern man or anthropoids, as an occasional occurrence. But even granted that this tubercle is typical of *Gigantopithecus*, it cannot be considered as a specialization which justified putting *Gigantopithecus* into a line completely separated from the other hominids on the basis of this specialization alone. The tubercle occurs in fossil and recent anthropoids (cf. tam, Pl. 10, a2, a3) as well as in modern man (tam, Pl. 10, d2) simply as a variation of the regular tooth pattern without any other morphological consequences or special accompanying structures.

Therefore, so long as there are no other evidences except those furnished by the teeth, the special place of *Gigantopithecus* in the evolutionary line can be determined only with some reservation. The pattern of the teeth indicates that he is a primitive hominid with closer relations to *Pithecanthropus* than to *Sinanthropus*. Their enormous size, which has no equivalent among the hominids or anthropoids, in any case, proves the uniqueness of his type. Nevertheless, that he is not so isolated as would appear at first glance is proved by the latest discoveries made in Java.

F. *GIGANTOPITHECUS* AS THE EARLIEST KNOWN HUMAN REPRESENTATIVE IN SOUTH CHINA

As has already been stated, the *Gigantopithecus* teeth were purchased by von Koenigswald in a Chinese dispensary in Hong Kong, together with teeth of deer, pig, carnivores, rodents, *Stegodon*, *Elephas*, and orang-utan. Two of the teeth, M_3 right and the upper molar, are without roots, while the third one, M_3 left, possesses only the posterior root; the anterior one is missing. The locality in which the *Gigantopithecus* teeth were bought, the character of the accompanying fauna, and the lost roots indicate with almost absolute certainty that the teeth came from caves in South China (Yunnan and Kwangsi). Their fauna and the cave deposits in which the bones and teeth are embedded have been described by C. C. Young,[1] H. C. Chang,[2] W. C. Pei,[3] and P. Teilhard de Chardin, C. C. Young, W. C. Pei, and H. C. Chang,[4] M. N. Bien and L. P. Chia,[5] and M. N. Bien.[6] According to these authorities all the caves which contain the bones and teeth are filled with the so-called "yellow deposits," and bones and teeth both have been gnawed off by porcupine (*Hystrix*), skeletal parts of which as

[1] Young, 1932a.
[2] Chang, 1934.
[3] Pei, 1935b.
[4] Teilhard de Chardin, Young, Pei, and Chang, 1935.
[5] Bien and Chia, 1938.
[6] Bien, 1940.

well as teeth are a usual occurrence in the bone material collected. The fauna represented by other bones or teeth consists of the following: *Ailuropus, Ursus, Hyaena ultima, Rhinoceros, Sus,* deer, *Bos, Stegodon,* tapir, *Elephas,* and orang-utan. This is exactly the same fauna von Koenigswald found assembled in the drawers of the Chinese dispensary in Hong Kong and from which he selected the *Gigantopithecus* teeth. Teilhard de Chardin and others,[1] discussing the yellow deposits in "Cave E" near Hsingan (north of Kweilin in Kwangsi Province where the aforementioned fauna was recovered *in situ*—see Fig. 27), stress the importance of this find as follows:

It explains the origin of so many teeth of *Stegodon, Ailuropus, Rhinoceros,* Tapir, etc. sold in the Kwangsi pharmaceutical shops. These remains have been excavated in the region from caves or fissures filled with the "yellow deposits."

The deposits and their fauna belong, according to these authorities, to the Lower or Middle Pleistocene and are contemporaneous with the fauna of Choukoutien which includes *Sinanthropus.* But no human bones or teeth were discovered in the caves of South China. Only Chang[2] describes, among the teeth of *Rhinoceros,* tapir, and other mammals, a fragment of the left side of a mandible containing two molars and two premolars with crowns broken off at the neck. He writes:

Judging from the shape as well as from the size of the lower jaw and the outline of the teeth, this lower jaw belongs undoubtedly to the group of Primates. For a closer study of it, better preserved material is needed.

Pei[3] goes further than Chang and refers to the specimen under the heading of "human remains." Chang does not give any precise indication from which cave or layer the mandible was collected; he speaks only generally of fossil mammals from limestone caves in Kweilin and Wuming (Kwangsi). Pei uses this "human mandible" as evidence of the presence of man in the "late" cave deposits of Kwangsi from which he described a mesolithic (?) stone industry. Chang's photographs[4] leave no doubt

that the mandible is that of a man; both bone and teeth are no larger than modern man, and there is no indication of any difference in structure. Therefore this find cannot be accepted as proof that there was a hominid contemporaneous with the Pleistocene cave fauna of South China.

However, there are other indications of man's presence. Teilhard and others[5] collected not merely the mammalian fauna alluded to above from the Kweilin "Cave E" but also "many shells (chiefly *Paludina*)." This strange assemblage induced the authors to make the further remark:

The origin of those remains [mixture of shells and bones] is obscure. . . . Two explanations can be proposed: a flood (the floor of the cave is 7 meters only over the flood plain)—or the presence of man. The first alternative is not supported by the nature of the deposits.

Pei[6] returns to this question in describing the mammals from the Kwangsi caves. He states:

No positive evidences of human occupation have so far been recognized in the *Stegodon* beds of South China; this absence being perhaps only due to the fact that no site belonging to this period has ever been scientifically investigated. . . . Other features are an indication, however, that human activity is partly responsible for the formation of such fossiliferous accumulations as those found in the "yellow deposits" of Kwangsi and Yunnan. Such is the curious abundance of *Sus* teeth and the puzzling association in the small cave "E" of an extreme variety of forms including such large animals as *Rhinoceros* and *Paludina* outside of any possibility of natural trapping and any evidence of flood.

There is still another hint in the literature pointing to the eventual presence of man. Pei,[7] in his paper on the mesolithic industry of the caves under discussion, describes an implement collected from Cave A in Wuminghsian. This implement is a quartzite core scraper which has been, according to Pei, worked twice. It was reworked from an older implement (I), much water-worn and patinated, which had, itself, been shaped "from a large original piece of quartzite" and had, later, been rejuvenated and shortened into "implement II."[8] Pei writes:

[1] Teilhard de Chardin, Young, Pei, and Chang, 1935.
[2] Chang, 1934, Pl. 3, Figs. 6, 7.
[3] Pei, 1935a.
[4] Chang, 1934, Pl. 3, Figs. 6, 7.

[5] Teilhard de Chardin, Young, Pei, and Chang, 1935.
[6] Pei, 1935b.
[7] Pei, 1935a.
[8] Pei, 1935a, Fig. 7, 401.

If "implement I" is more than a deceptive appearance, the age is evidently widely different from that of the other artifacts described in this paper. And then we should hold in Kwangsi the trace of a very old Paleolithic industry.

Finally, Bien and Chia[1] report that pieces of burnt bones and charcoal were frequently discovered in the cave and rock-shelter deposits of Yunnan. Also, two flint flakes found inside bore some traces of artificial breakage. Although the authors consider that these facts indicate human activity, nevertheless they are very cautious in their definite conclusions and hope for "more favorable localities with better remains of Mesolithic or even late Palaeolithic time."

From this review of our knowledge of the presence of man in the caves of South China, it follows that his presence in the Lower or Middle Pleistocene layers cannot be taken as proved by the data so far produced. The mandible fragment, as well as the implement, seems to belong to a much later time. But the strange assemblages of mammal bones recorded as found with shells[2] and the abundance of pig bones[3] may be interpreted as a possible sign of human activity. The newly acquired information that *Gigantopithecus*, which belongs to the Lower or Middle Pleistocene fauna of the Kwangsi caves, is not a great ape, as von Koenigswald supposed, but a true hominid extends our knowledge of the South China caves in several directions.

First, as surely as a hominid, *Sinanthropus pekinensis*, lived in the caves of North China (Choukoutien) just as surely was there also a hominid in the contemporaneous caves of South China. Second, just as the South China cave

fauna differed from that of North China,[4] so there also existed a difference in the human type. Even if the enormous difference in size between *Gigantopithecus* and *Sinanthropus* be dismissed, there is still a difference in the tooth pattern which indicates that the former was not merely a giant type of the latter, but that each represents a distinct form. Their relations to each other will be discussed later.

The *Stegodon* and orang-utan fauna of the South China caves is characterized by its "Malayan affinities."[5] This same likeness induced von Koenigswald[6] to speak of a common "Sino-Malayan fauna," extending from South China to Java. Indeed *Stegodon*, *Rhinoceros*, tapir, and orang-utan are characteristic representatives of the Trinil bed fauna of Java and contemporaneous with *Pithecanthropus erectus*.[7] Such common association brings *Gigantopithecus* closer to *Pithecanthropus* than to *Sinanthropus*. Also, as I have shown in preceding sections, the *Gigantopithecus* teeth agree more in some features—size being disregarded—with the teeth of *Pithecanthropus* Mandible B and those of the maxilla of *Pithecanthropus robustus*. But von Koenigswald's new discovery of *Meganthropus* with its large teeth proves that even the size of the *Gigantopithecus* teeth offers an indication of a closer relationship between *Gigantopithecus* and the Java hominids ranged under the name of *Pithecanthropus* and *Meganthropus*. Before entering into this discussion, however, we must first revert to the *Meganthropus* and *Pithecanthropus* problem.

[1] Bien and Chia, 1938.

[2] Teilhard de Chardin, Young, Pei, and Chang, 1935.

[3] Pei, 1935b.

[4] Teilhard de Chardin, Young, Pei, and Chang, 1935; *Stegodon*, tapir, orang-utan characteristic of the South China fauna; euryceroid deer and *Dicerorhinus* characteristic of the North China fauna.

[5] Teilhard de Chardin, Young, Pei, and Chang, 1935.

[6] Von Koenigswald, 1938–1939.

[7] Von Koenigswald, 1938–1939, 1939; de Terra, H., 1943b.

VI. THE *PITHECANTHROPUS* PROBLEM

THE FIRST SECTION OF THIS STUDY recorded, together with their dates and sites, the earlier and latest discoveries which von Koenigswald was so fortunate as to make in Java. The list in Table 17 shows that, if the infant skull of *Homo modjokertensis* is omitted, these discoveries represent three skulls (*Pithecanthropus* Skulls II, III, and IV), three mandibles (*Pithecanthropus* Mandible B, the Sangiran Mandible of 1939, and the Sangiran Mandible of 1941), and one maxilla undoubtedly belonging to *Pithecanthropus* Skull IV. All these specimens came from the Trinil bed of the Sangiran District. To these skulls must be added Dubois' Trinil skull, the holotype of *Pithecanthropus erectus* (*Pithecanthropus* Skull I), which was recovered from another locality, the left bank of the Solo (Bengawan) River near Trinil, which gave its name to the geological formation in which the skull was embedded. In my paper on the *Sinanthropus* skull[1] I indicated that our classification of the hominids recovered from the Trinil bed layer needs a correction. Dubois, who coined the name *Pithecanthropus*, considered his type to be neither an anthropoid nor a hominid but a "giant gibbon," intermediate between gibbon and man. He did not hesitate to attribute each bone or tooth with hominid-like features to *Pithecanthropus*, if the specimen was found in geological formations identical with those of Trinil. If the skeletal parts lay close together, he even assigned them to the same individual, since he was always possessed by the idea that there can be only *one* primate type with hominid trends in a single geological formation. For this reason the Trinil femur and three teeth found in the same general location as the Trinil skull cap were also regarded as the remains of the same *Pithecanthropus* skeleton, although they were scattered over an area of about 45 square feet. During the time which has elapsed since their discovery, it has become increasingly evident that the three teeth belong to two different types. The two molars are those of an orangutan, and the premolar is that of a man. I shall revert to these later.[2] The real nature of the

Trinil femur, however, still remained unsettled. In size and form it is exactly like any femur of modern man. In recent years Dubois discovered five more femora. These were found in a box containing mammalian ribs, collected 40 years before in Java, and stored during the interim at the Leiden Museum. The discovery of these femora, all of modern human type, did not solve the problem as Dubois expected. They confused it still more, because of the difficulty in identifying the site and the particular horizon where they were found, and, further, because the bones themselves differ in size and form from the original Trinil femur.[3]

Dubois, prompted by the same consideration which had influenced him earlier, when von Koenigswald[4] discovered the fragment of a hominid mandible in the Trinil bed of the Sangiran District, did not hesitate to describe it as a jaw of *Pithecanthropus*. However, by this time a mandible attributed to *Pithecanthropus* was already known. In 1890, one year before the discovery of the skull cap, Dubois collected the fragment of a lower jaw from the Kendeng deposits. This is listed under the name of the mandible of Kedung Brubus (*Pithecanthropus* Mandible A according to von Koenigswald and Weidenreich).[5] The Kendeng deposits yielded the same fauna as that from the bank of the Solo River near Trinil, and for this reason Dubois had attributed the fragment of Kedung Brubus to *Pithecanthropus*. This fragment was first described and figured by Dubois in 1924, but attracted little attention, either then or later, apparently because of its poor condition. It consists (Pl. 9, c1, c2; Fig. 26) of a small triangular piece of the right buccal and adjacent surface of the mandibular body, in the region of the first premolar and canine. The jaw is low and relatively thick. Its height, measured at the interstice between P_1 and P_2, is 27 mm.; the thickness at the same level is 17 mm. The buccal surface (c1), as far as it is preserved, has no special feature except a slight torus marginalis, but the aspect of the lower surface (c2) is surprising. Extending from the

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[1] Weidenreich, 1943b.
[2] For literature see Weidenreich, 1937a.

[3] For literature and details see Weidenreich, 1941a.
[4] Von Koenigswald, 1937.
[5] Von Koenigswald and Weidenreich, 1939.

TABLE 17

LIST OF SKELETAL PARTS OF HOMINID FORMS RECOVERED FROM THE TRINIL BEDS OF JAVA

Specimen	Year of Discovery	Site	When and by Whom Recognized	Attributed to:	Alleged General Zoological Character	Later Referred to as:	Revised Classification
Mandible	1890	Kedung-Brubus	Dubois, 1924	*Pithecanthropus erectus*	Giant gibbon (intermediate)	Mandible A	Hominid: possibly *Pithecanthropus erectus*
Tooth (right M³)	1891	Trinil	Dubois, 1894	*Pithecanthropus erectus*	Giant gibbon (intermediate)	—	Not human, orang-utan
Skull cap	1891	Trinil	Dubois, 1894	*Pithecanthropus erectus*	Giant gibbon (intermediate)	*Pithecanthropus* Skull I	Hominid: *Pithecanthropus erectus* Skull I
Left femur	1892	Trinil	Dubois, 1894	*Pithecanthropus erectus*	Giant gibbon (intermediate)	Trinil femur	Hominid: *Pithecanthropus? Homo sapiens?*
Tooth (left M²)	1892	Trinil	Dubois, 1924	*Pithecanthropus erectus*	Giant gibbon (intermediate)	—	Not human, orang-utan
Tooth (left P₁)	1898 (?)	Trinil	Dubois, 1924	*Pithecanthropus erectus*	Giant gibbon (intermediate)	—	Hominid: *Pithecanthropus? Homo sapiens?*
Five femora	1900	Trinil (?)	Dubois, 1932–1935	*Pithecanthropus erectus*	Giant gibbon (intermediate)	Leiden femora	Hominid: *Pithecanthropus? Homo sapiens?*
Mandible	1937	Sangiran	Von Koenigswald, 1937	*Pithecanthropus erectus*	Hominid	Mandible B	Hominid: *Pithecanthropus erectus*
Skull cap	1938	Sangiran	Von Koenigswald, 1938	*Pithecanthropus erectus*	Hominid	*Pithecanthropus* Skull II	Hominid: *Pithecanthropus erectus* Skull II
Skull fragment	1938	Sangiran	Von Koenigswald and Weidenreich, 1938	*Pithecanthropus erectus*	Hominid	*Pithecanthropus* Skull III	Hominid: *Pithecanthropus erectus* Skull III
Skull cap and maxilla	1939	Sangiran	Von Koenigswald and Weidenreich, 1939	*Pithecanthropus erectus*	Hominid	*Pithecanthropus* Skull IV, male	Hominid: *Pithecanthropus robustus* Weidenreich
Mandible	1939	Sangiran	Von Koenigswald, 1941	*Meganthropus palaeo-javanicus*, female	Hominid	*Meganthropus*, female	Indeterminable: hominid? anthropoid?
Mandible	1941	Sangiran	Von Koenigswald, 1941	*Meganthropus palaeo-javanicus*, male	Hominid	*Meganthropus*, male	Hominid: *Meganthropus palaeojavanicus* von Koenigswald

buccal to the lingual margin, the entire surface of the fragment, measuring about 16 mm. in breadth, is occupied by a broad, smooth, and slightly concave plane. Such a formation in a mandible is strange for any primate—ape or hominid. But this plane is not artificially produced by erosion or wear from rolling about, for there is not the slightest indication on which to base such an assumption. The area can be interpreted only as a digastric fossa, unusual in size and position.[1] Following Dubois, I attributed this unquestionably hominid mandible to *Pithecanthropus* or, eventually, to *Homo soloensis*, the other type of early man known at this time from the Pleistocene of Java.

The similarity of the fossa, in general size and position, between the Kendeng mandible and that of *Sinanthropus* persuaded me to acknowledge its *Pithecanthropus* character. In *Sinanthropus*, too, the digastric fossa occupies the entire lower surface of the mandible from the buccal to the lingual border. Furthermore, it is a smooth and slightly concave area. Nevertheless, it differs from the fossa in the Kendeng jaw, for it never attains the breadth of the latter. In Mandible H, in which the breadth of the fossa is greatest, it is only 7.7 mm.; the labio-lingual diameter of the fossa of modern man varies from 5.0 to 7.5 mm. according to H. Virchow.

Von Koenigswald's *Pithecanthropus* Mandible B (Figs. 8a–c, 27; Pl. 8d) is somewhat higher than the Kendeng mandible, but thicker distally, if the measurements are taken at the same level. The essential difference, once again, concerns the digastric fossa. Its position in both cases is the same, but the greatest breadth of the Mandible B fossa does not exceed 10 mm. One other difference is that Mandible B has three relatively small mental foramina (Fig. 8a), the same condition as that found in *Sinanthropus*. However, Mandible A seemed to possess only a single large opening (Pl. 9, c1). In regard to the teeth, the alveolus of the canine, which is preserved in both mandibles, although the teeth themselves are missing, indicates a small canine with a root compressed in mesio-distal direction. The upper portion of the root, the one part of the first premolar that is preserved in Mandible A, reveals a tooth of about

the same size and form as that of Mandible B where only the alveolus is also preserved. I think it may not be incorrect to assume that the features held in common by Mandible A and Mandible B are of greater value in classifying them than are the features in which they disagree. If so, we may be correct in attributing both to the same type—*Pithecanthropus*. Nevertheless, it must be remembered that the existing differences, particularly the breadth of the digastric fossa, far exceed any individual variations so far known to occur in anthropoids or in recent man.

Pithecanthropus Skull II, discovered by von Koenigswald in the Trinil bed of Sangiran (1938), resembles Dubois' skull cap of Trinil (the holotype of *Pithecanthropus*, called Skull I) in general form and detail of structure to such a degree that they seem almost identical (Figs. 4–7).[2] They differ only in that Skull II is smaller than Skull I (cranial capacity of the former is 775 cc. compared with 935 cc. for the latter). This difference in size does not exceed the limit of individual variation.

Pithecanthropus Skull III[3] is more fragmentary than Skulls I and II. It represents a young individual with the cranial sutures open wide, while in Skulls I and II the sutures are closed and only partly discernible. Nevertheless, Skull III is of the *Pithecanthropus* type, characterized by the special form of the skull cap with its greatest breadth at the base decreasing gradually toward the parietal tuberosity and the top, the presence of a sagittal crest, and a parasagittal depression.[4]

As no facial bones have been found with any of the three skull caps, it is difficult to decide whether the mandible of Kedung Brubus (Mandible A) and the Sangiran Mandible B belong to the *Pithecanthropus erectus* type, as represented by the skull caps. If the size of the *Pithecanthropus* skulls and mandibles is taken as the basis for comparison, the two adult *Pithecanthropus* skulls are smaller than the adult female *Sinanthropus* Skull XI. The *Sinanthro-*

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[1] Weidenreich, 1936.

[2] See also the comparative illustrations in von Koenigswald, 1942, Pl. 1, Figs. 1–4; Pl. 2, Figs. 1–4; and Weidenreich, 1943b, Pl. 86, Figs. 259, 260.

[3] Von Koenigswald and Weidenreich, 1938; for illustrations see von Koenigswald, 1942, Pl. 7, Fig. 1; Weidenreich, 1943b, Pl. 82, Fig. 247; Pl. 87, Fig. 261.

[4] Von Koenigswald and Weidenreich, 1938; Weidenreich, 1938, 1943b.

pus Mandibles A and H I[1] correspond in size to Skull XI. However, as these two jaws are much smaller than *Pithecanthropus* Mandible B, it is safe to state that Mandible B is too large for *Pithecanthropus* Skulls I and II. When Skull II was found, von Koenigswald was inclined to consider it as a female skull and Skull I (Trinil) as a male because of the differences in size. If this identification is correct, there would be no place for Mandible B since it is even too big for the male Skull I.

The discovery of *Pithecanthropus* Skull IV offered no solution for this dilemma; on the contrary, it aggravated the situation. Since this skull was found in the Trinil bed at Sangiran, neither von Koenigswald nor I[2] had any scruples in assigning it to the *Pithecanthropus erectus* type, in spite of the fact that the skull, as a whole, was much larger and more massive than the Trinil skull and still more so than Skull II. I tried to get out of the impasse by resorting again to sex differences. Skull IV was now regarded as male, consequently Skull I, together with Skull II, had to be designated as female, interpreting the special differences in size merely as individual variations. Skull IV was large enough so that it was possible to adjust Mandible B to it without violating the harmony of the form unduly, as I have shown in my reconstruction (Pl. 4a, b; Pl. 5a). Nevertheless, to attribute Skull IV to *Pithecanthropus erectus* raises some difficulties which cannot be dismissed as mere individual variations without any classificatory significance. As I said earlier it is difficult to account for six features, if we hold to the conception that *Pithecanthropus*, as a type, is very close to *Sinanthropus*. Such a conception is suggested by the conformity of *Pithecanthropus* Skull I and particularly of Skull II with *Sinanthropus*[3] and fortified by the strong agreement in general form and details between *Pithecanthropus* Mandible B and the *Sinanthropus* mandibles. The six contrasting features are: 1, the extraordinary massiveness of the skull; 2, the unusual development of the sagittal crest and its disintegration into some isolated knobs; 3, the presence of a distinct diastema between upper canine and lateral

incisor; 4, the enormous size and width of the palate; 5, the complete smoothness of the palate which lacks any rugosity whatever; 6, the distinct predominance of M[2] in size over M[1] and M[3]. None of these features is found in *Sinanthropus*, nor do the first two occur in the *Pithecanthropus* Skulls I or II. Since no maxilla of the *Pithecanthropus erectus* holotype is preserved, it is impossible to check features three to six as to whether or not they occur in the type. On the other hand, the discovery of the maxilla of Skull IV makes it possible to bring one of the many puzzles of the *Pithecanthropus* problem nearer to its solution. As mentioned above, near the Trinil skull cap Dubois found three teeth which he attributed to *Pithecanthropus*. Two of these teeth were upper molars, one a third and the other also a third, or possibly a second, upper molar. G. S. Miller, Jr.,[4] compared these teeth with the corresponding teeth of recent orang-utan and concluded that the so-called *Pithecanthropus* molars are orang-utan teeth. He writes:

... The only characters ... that appear to be outside the limits of individual variations in our series of recent orangs are: (a) in both teeth a tendency for the posterior side of the crown to bulge out beyond the level of the roots; (b) in the second molar the absence of this tendency to bulge outward along the anterior margin; and (c) in the third molars the wide angle of divergence of the roots. These differences point to a probable specific distinctness of the extinct Java ape from the living ones of Borneo and Sumatra.

In Pl. 12m the third molar of *"Pithecanthropus"* (1), taken from Dubois' own publication,[5] and a third molar of an orang-utan from Miller's collection (2) are illustrated side by side. The teeth are very similar, having in common especially the relatively small, oval, occlusal surface while the buccal, lingual, and distal sides of the crowns, not leveled by contact with the second molar, bulge out to an extent quite unusual in hominids (*Sinanthropus*) or in other anthropoids except orang-utan. Indeed, the right third molar of *Pithecanthropus* Skull IV (Pl. 12i) displays a distinctly hominid character and is quite different from Dubois' alleged *Pithecanthropus* tooth. See particularly the hominid "flower-bud" pattern of the paracone

[1] Weidenreich, 1936.

[2] Von Koenigswald and Weidenreich, 1939; Weidenreich, 1940a, 1940b, 1941b.

[3] Von Koenigswald and Weidenreich, 1938, 1939.

[4] Miller, 1923.

[5] Dubois, 1924.

(fb). As Skull IV undoubtedly reveals more primitive peculiarities than Trinil Skull I, the upper molars found with the latter cannot be more anthropoid—or, more correctly, more orang-like—than the former should they really belong to the skull. In other words, the upper molars of Trinil are not hominid teeth, and their association with the skull of a hominid is purely accidental.

The discovery of the Sangiran Mandible of 1939 did not help in solving the *Pithecanthropus* problem. Its imperfect condition makes it impossible (at least while neither the original specimen nor a skiagram of it are available) to decide whether the fragment belongs to a hominid or, as I deem more probable, to an anthropoid. But, even in the latter case, it must be admitted that this anthropoid has a shorter snout than any known form, recent or fossil. However this may be, it is certain that the mandible of 1939 cannot be regarded as a female of a giant type represented by the *Meganthropus* mandible as von Koenigswald believes. Actually, it is an addition to the series of different types with hominid characters (or a trace of them) discovered in the Trinil beds of Java. This fact alone deepens the doubt about the typological homogeneity of the finds collected from the same geological horizon.

In spite of its extraordinary massiveness and size, the Sangiran Mandible of 1941 attributed to "*Meganthropus palaeojavanicus*" by von Koenigswald is undoubtedly a true hominid. This is proved by the following facts: The canine is small; the first premolar is a bicuspid and not a sectorial tooth. The mid-sagittal section through the symphysis shows the typical pattern of the hominids. This is also true of the whole lingual side of this region; it reveals a moderate torus transversus superior, a small fossa genioglossi, and the first indication of a mental spine consisting of two separated upper tubercles and a single lower one. The mental foramen is situated about in the middle of the height and faces sideward and slightly backward. In naming this specimen *Meganthropus*, von Koenigswald recognized that the form differs from that of the *Pithecanthropus* Mandibles A and B so markedly that a proper name is justified. In other words, he recognized that the specimen does not conform to the holotype of *Pithecanthropus erectus*. This is

certainly true. But, if so, the question immediately arises: What is the relationship between *Meganthropus* and *Pithecanthropus?* Both are hominids; both came from the same geological horizon and even from the same site, the Trinil beds of Sangiran. The *Pithecanthropus* mandible of Kedung Brubus compared with that of *Meganthropus* looks like a dwarf (Fig. 26). Quite apart from this difference in size, the *Pithecanthropus* specimen of Kedung Brubus (Mandible A) has an extraordinarily large digastric fossa situated entirely on the lower surface (Pl. 9, c2). The Sangiran mandible of 1937, *Pithecanthropus* Mandible B, is larger than Mandible A, but its digastric fossa, although narrower than that of Mandible A, occupies the same place (Fig. 8c). On the other hand, the fact that a special recessus digastricus exists in *Meganthropus* and that its digastric fossa is placed entirely on the lingual side within this recessus (Pl. 8a) makes it so divergent from hominids and anthropoids alike that these peculiarities cannot be dismissed as mere individual variations from the holotype. Certain specific features, together with the giant size of the mandible, argue for the separation of this type from *Pithecanthropus*. But, in agreeing that this is true, I again wish to stress the position I have taken in questions involving hominid nomenclature and which I have discussed in my paper on the *Sinanthropus* skull.[1] I do not believe that *Meganthropus* is "generically" different from *Pithecanthropus*, as the name, when used in the strictly taxonomic sense, may suggest. *Meganthropus* represents a giant type, the features of which far surpass the limits of the range of individual variations.

The discovery of *Meganthropus* also throws new light on the so-called *Pithecanthropus* Skull IV. This skull differs from *Pithecanthropus* Skulls I and II to such a degree that it cannot be referred to the *Pithecanthropus erectus* holotype with any more justification than can *Meganthropus*. Its massiveness and general size indicate that it comes somewhat closer to *Meganthropus* than to the *Pithecanthropus* type. Which of the two mandibles, the *Pithecanthropus* Mandible B or the *Meganthropus* mandible, better fits the maxilla of Skull IV can best be judged by using the size of the teeth as a criterion. When Mandible B is adjusted to the

[1] Weidenreich, 1943b.

skull, the length of the premolar-molar series is about the same; the upper one only slightly exceeds the lower. When, however, the restored *Meganthropus* mandible is so adjusted, the lower row exceeds the upper one considerably. I tried to discover the ratio of the size of the lower premolars and molars to the size of the upper molars (Fig. 25). If the size of the crowns is expressed by their rectangles (length $\times$ breadth), there is only a negligible difference between the corresponding upper and lower teeth of recent man as Fig. 25c shows. That is to say, P^1, P^2, M^1, and M^2 are the same size as P_1, P_2, M_1, and M_2, respectively. In *Sinanthropus* (Fig. 25b) the second premolars and the first molars are the same size, but the upper first premolar is larger than the lower first premolar, while the lower second molar is larger than the upper second molar. However, it must be kept in mind that the differences in *Sinanthropus* may be due to the relatively small number of teeth available for such statistical use. Among the anthropoids, differences in tooth size are smallest in orang-utan (female) and greatest in gorilla (female); in chimpanzee (male and female) the lower first premolar is considerably larger than the upper one. As to the other teeth, chimpanzee agrees with gorilla and orang-utan in that their lower premolars and molars are larger than their upper ones. In *Pithecanthropus* Mandible B, P_2, M_1, and M_2 are available, as are P_1, P_2, and M_1 of the *Meganthropus* mandible, for comparison with P^1, P^2, M^1, and M^2 of the *Pithecanthropus* Skull IV. The comparison (Fig. 25a) reveals that the lower teeth of Mandible B are equal in size to the corresponding upper ones of Skull IV, except the second molars, where the upper one of Skull IV considerably exceeds the lower one of Mandible B. However, all three lower teeth of *Meganthropus* are considerably larger than the corresponding upper teeth of Skull IV.

From this comparison it follows that the size of *Pithecanthropus* Mandible B may correspond to a calvarium about the size of the *Pithecanthropus* Skull IV, although the size of the upper second molar of Skull IV (Fig. 25a) suggests that the mandible pertaining to it may have been larger than the Mandible B. On the other hand, there can be no doubt that Skull IV is much too small for a mandible with teeth like those of *Meganthropus*. In other words, *Megan-*

thropus had a skull which far exceeded *Pithecanthropus* Skull IV in size and (it may safely be added) in massiveness. But it would be fallacious to conclude from the same facts that Mandible B must have belonged to a calvarium of Skull IV type. For, as has been shown above, Mandible B bears all the characteristics of a form similar to *Sinanthropus*, whereas Skull IV exhibits some primitive and peculiar features which are lacking not only in *Sinanthropus* but also in the holotype of *Pithecanthropus*.

Therefore, the classification of the hominid remains discovered in the Trinil bed of Java needs some essential corrections (cf. Table 17). If the Trinil skull cap (*Pithecanthropus* Skull I), von Koenigswald's Sangiran calvaria (*Pithecanthropus* Skull II), and the imperfect juvenile Sangiran calotte (*Pithecanthropus* Skull III) are all considered as belonging to that hominid type to which the name *Pithecanthropus erectus* has been given by Dubois, then it is safer, as the matter now stands, to keep Skull IV apart. I believed at first that the morphological differences between the skulls in question could be eliminated as mere differences in sex, Skull IV representing a male and Skulls I and II females. However, as already stressed, the differences are too fundamental to allow such an interpretation. As no maxilla of Skull I or Skull II is available for comparison with the maxilla of Skull IV, only the character of the brain case can be used as a gauge for comparison with modern man and *Sinanthropus*, on the one hand, and with recent anthropoids, on the other. In living hominids sexual differences are revealed in the size of the brain case and, to a certain extent, in the development of its constituent bones and superstructures.[1] In *Sinanthropus* and the anthropoids, the difference is restricted to the size and development of the superstructures influencing only slightly the size and development of the brain case. However, the massiveness and size of the bones and the size and character of the superstructures of Skull IV exceed the corresponding features of Skulls I and II to a degree unequaled in comparable living or fossil forms of the same type. Skull IV certainly reveals a gigantism which transcends any sexual difference in size or development that may occur in primates. The occurrence of gigantism among the hominids of

[1] Weidenreich, 1940b, 1941b, 1943b.

Java is proved by the existence of the Sangiran Mandible of 1941. Von Koenigswald certainly is justified in separating this form from *Pithecanthropus* and naming it *Meganthropus* for, in this case, the differences in size and form are obviously too great to be interpreted as being due to sex. The relation between large and small forms will be discussed in the following section. In any case, the great differences in size and the forms. Although from South China, *Gigantopithecus* can be added to this list of Java hominids, because it is a member of the Sino-Malayan fauna and, as such, closely connected with the hominids of Java. (See p. 94.) In *Gigantopithecus* the trend to gigantic hominid forms apparently reached a climax.

At first glance it seems strange that such a multitude of hominid forms, at once similar yet
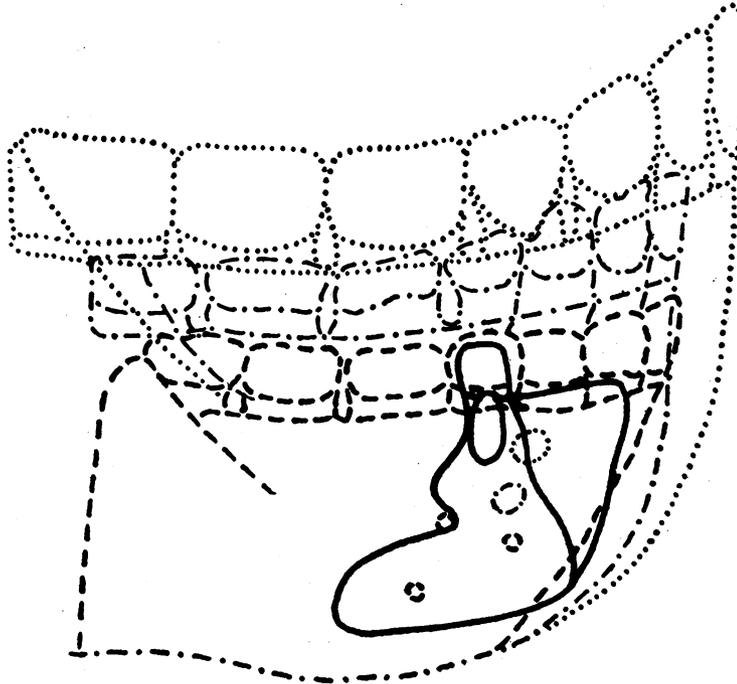
Fig. 26. Outlines of the bodies of the mandibles of Kedung Brubus (—), *Pithecanthropus* Mandible B (- - -), *Meganthropus* reconstructed (- . -), and *Gigantopithecus*, constructed on the basis of the size of M₃ (. . . .).

divergence in certain structures demonstrate that the Java hominids from the Trinil formation are not so homogeneous that they may be classed as *one* type.

Even if we set aside the dubious Sangiran Mandible of 1939, there remain the Kedung Brubus mandible (referred to *Pithecanthropus erectus*), the Sangiran Mandible B (also referred to *Pithecanthropus erectus*), and the Sangiran Mandible of 1941 (referred to *Meganthropus*). These differ in size, each being larger than the preceding (Fig. 26), and in the form and position of the digastric fossa so that we can be certain that they represent different hominid

divergent, should have their origin in the same geological horizon. Doubtless all were recovered from the Trinil beds and all were associated with the same fauna. Many more, and more thorough investigations are needed in the future to decide with certainty whether or not all these forms, found in the Trinil beds, were really contemporaneous.

De Terra,[1] referring to Duyfjes, describes the events which led to the formation of the Trinil bone bed of the Madioen Plain between Trinil and Ngandong, as follows:

[1] De Terra, H., 1943b.

This period (Lower and Middle Pleistocene) was one of great volcanic activity during which streams were repeatedly ponded as a result of the lava and mudflows which advanced onto the Madioen Plain. Doubtless the river built its flood-plain higher and higher, and its southern tributaries swept down from the ever rising slopes of the Lawoe volcano, bringing with them the remains of those animals and plants which thrived in the adjoining hills. It is this combination of erosion on the volcanic upland and rapid accumulation in the river flat, together with catastrophic mud flows and ash falls, which accounts for the abundance of fossil remains in this region. But since the depositional agencies lacked regularity and gentleness of action, most of the fossils were embedded in fragmentary conditions.

Those violent mud streams may have washed out the deeper and older deposits and redeposited the material, with or without matrix, in more recent formations. The hominid specimens are in fragmentary condition and, obviously, have been transported by mud streams or water in the place from which they have been recovered. Their true dwelling places, the precise time in which they lived and how they died are so far unknown; we can speculate on it, but there is no certainty. Volcanic eruptions, with consequent mud and water torrents, which excavated the soil were not at all restricted to the Lower and Middle Pleistocene, but also occurred at later times, even to the present. De Terra, discussing the question of the contemporaneity of *Pithecanthropus* and modern man in the bone beds of Trinil does not discount the possibility that there was "some redisposition in the Trinil horizon during Late Pleistocene or even Post-Pleistocene times." Concerning the lake deposits of Sangiran where the new finds were made, and referring to Van Es'[1] description of the origin of the volcanic mud-conglomerate, the so-called "lahar" deposit, de Terra writes:

It is this dual role of mass-movement and scooping or erosive power which makes a lahar deposit a very puzzling geological feature. For one thing the *capacity of scooping and picking up older sediments* explains why, at Sangiran, patches and lumps of older marine clays were found in the volcanic boulder breccia. Also it would seem that such a formation *might pick up bones or plant remains and transport them a considerable distance, necessitating special care*

[1] Van Es, 1931.

in the interpretation of geological sections.[2] [Italics mine.]

In the face of all these facts and possibilities we must adhere strictly to the point of view that I have recently maintained; that is, only on the basis of morphological characters can one decide first, whether different specimens found in the same place or in nearby places belong to the same individual or type, and second, which is the more primitive and, therefore, the older one structurally. As long as our knowledge of the evolutionary stages of early man is as scanty as it is now and as long as the geological data are ambiguous, we cannot disentangle the existing confusion when we consider only the geological horizon as the decisive criterion.

In the case of Dubois' Trinil finds, for example, the skull cap represents a primitive hominid as has been proved by the discovery of the more complete calvaria of Sangiran (Skull II) with their great resemblance to the calvaria of *Sinanthropus pekinensis*. The name "*Pithecanthropus erectus*" given by Dubois to the Trinil skull cap can, therefore, also be applied to this Sangiran specimen. The Trinil femur, however, in general form as well as detailed structure, has the characteristics of modern man. The geological data do not offer unequivocal evidence that it *must* have been part of the same skeleton as the skull cap. With equal reason it may be assumed that the femur belonged to a skeleton of modern man who may have appeared in Java much later, but whose bones may have been deposited in the Trinil horizon subsequently by such agencies as we have previously mentioned. On the other hand, as the matter now stands, it is not absolutely impossible that *Pithecanthropus erectus* combined a femur with the characteristics of those of modern man with a much more primitive skull, as Dubois took for granted. Such an assumption finds some support in the evidence, provided by *Sinanthropus*, that a femur which differs only slightly from that of modern man is nevertheless compatible with a much more primitive skull. Man apparently acquired his erect posture long before his skull underwent the characteristic transformation into the modern human type. In the case of *Pithecanthropus*, however, the situation is a little different: 1, the

[2] De Terra, H., 1943b.

Trinil femur is more like that of modern man than is the *Sinanthropus* femur[1]; 2, the new Java finds indicate that the *Pithecanthropus* skull does not correspond to the form of modern man any more closely than does *Sinanthropus*; 3, the possibility that earlier and later skeletal elements may have mixed can be excluded more safely in the case of *Sinanthropus* than in that of *Pithecanthropus*. The doubt concerning the primitive character of the Trinil femur has been increased by Dubois' discovery of five additional femora which, although allegedly from the Trinil beds of Java, all display modern human characteristics. But only one of these femur fragments corresponds to the original Trinil find; the four remaining differ in form and details, not only from the original femur, but from one another.[2]

There remains another possibility. As I suggested in my paper on the *Sinanthropus* skull,[3] it is quite possible that all the femora belonged to *Homo soloensis*, who must be considered as a hominid type more advanced than *Pithecanthropus*. The tibia of *Homo soloensis*, preserved with the skulls, already bears all the main characteristics of modern man, so that it is safe to infer the same relation for the femora attributed to *Pithecanthropus*. *Homo soloensis* remains have been recovered from the Upper Pleistocene terraces of the Solo River, some miles down stream from Trinil. There is every reason to believe that these terraces once extended up stream to Trinil and even beyond; and also that they contained remains of *Homo soloensis*; and that, at a much later time, this terrace soil was eroded and washed into older formations where they were mixed with the bones peculiar to *Pithecanthropus*.

As to the three teeth found in the same place as the Trinil skull cap and femur, the two molars are certainly orang-utan teeth, as we have already stated. Orang-utan teeth of fossil and sub-fossil character are a common occurrence in the Trinil and later formations. They do not differ fundamentally from the teeth of living orang-utan. The third Trinil tooth, a first lower premolar, cannot be distinguished from the tooth of a modern man. As I set forth in my

paper on the *Sinanthropus* dentition,[4] this premolar is not only too small, in proportion to the large molars attributed to *Pithecanthropus*, to belong with them, but is too small even to be considered as the tooth of a primitive hominid. When I arrived at these conclusions, no first premolar of an early Java hominid was known, so that I based my deductions on a comparison with the *Sinanthropus* teeth. Meantime, both the Sangiran Mandible B, which contains the second, although not the first premolar, and the *Meganthropus* mandible have become available. The Trinil premolar is certainly smaller than the former and considerably smaller than the latter. Size apart, however, the *Meganthropus* premolar has very clear remains of a cingulum, a feature which is also indicated in the second premolar of the Mandible B. Relics of cingula are normal occurrences in the *Sinanthropus* premolars, while they are completely lacking in the premolars of Neanderthalians and modern man. All these facts necessitate the conclusion that the Trinil premolar is the tooth of a modern man or perhaps of an earlier hominid type like *Homo soloensis*.

If an attempt is made to classify the 17 hominid skeletal elements (Table 17) recorded from the Trinil beds of Kedung Brubus, Trinil, and Sangiran and to arrange them, tentatively, according to their degree of primitiveness, using only morphological characteristics as criteria, we arrive at the following list:

1. The most primitive specimen is the Sangiran Mandible of 1941, which von Koenigswald has already separated from the classic *Pithecanthropus* and given the name of *Meganthropus palaeojavanicus*.

2. The next is the *Pithecanthropus* Skull IV consisting of a fragmentary brain case and maxilla.

3. Then follows the Sangiran Mandible of 1937 (*Pithecanthropus* Mandible B).

4. Next are the Trinil skull cap (*Pithecanthropus* Skull I), von Koenigswald's Sangiran calvaria (*Pithecanthropus* Skull II), and the juvenile Sangiran calotte (*Pithecanthropus* Skull III).

5. We then come to the Dubois mandible of Kedung Brubus (*Pithecanthropus* Mandible A). Whether this can be placed with Group IV or

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[1] Weidenreich, 1941a.
[2] Weidenreich, 1941a.
[3] Weidenreich, 1943b.

[4] Weidenreich, 1937a.

not remains doubtful. It seems closer to modern man than to the Mandible B of Group III, the only mandible so far available for comparison. I include it in this special group with reservations.

6. The Trinil femur and the five Leiden femora are so like modern man that they, too, should be placed in a special group. They may belong to *Homo soloensis* or a similar type rather than to the *Pithecanthropus* or to an earlier hominid group, although this possibility cannot be excluded. The Trinil premolar must also be placed in this group, although there is less possibility that it belongs to an earlier stage than is the case of the femora.

Only three specimens remain: the two Trinil teeth and the Sangiran Mandible of 1939. The teeth must be excluded from a list of hominid remains because they are those of an orangutan, possibly of a special fossil type. The position of the mandible cannot be assigned on the basis of the material available at present. If it is a hominid, as von Koenigswald claims, then it represents a very primitive, special group; but in no case is it a female *Meganthropus*. If it is an anthropoid, as I assume, then it likewise belongs in a special group, close to orang-utan, but different from the living type. The confusion caused by the present usage of the different names and by the necessity of referring to specimens by the site and year of their discovery calls for the assignment of precise and adequate names. But the crux of taxonomic nomenclature is that, once given, the name adheres to the form, even though the presumption which led to its designation later turns out to have been erroneous. The name *Gigantopithecus* will cling to the teeth and the type, even though the type is certainly not a "pithecus" but an "anthropus." On the other hand, the introduction of new names, whether generic or specific in the strict taxonomic sense, leads some people to believe that those hominid forms with new labels must be considered as generically or specifically different from hominids with other labels and, therefore, as representatives of completely independent branches of the human family tree. In my paper on the *Sinanthropus* skull,[1] and in other previous publications, I set forth the concept that morphological differences in the hominid family, particularly if due

to evolutionary transformation are not such as to exclude interbreeding or the continuation of the different lines into the variant races of modern mankind.

For practical reasons, especially to facilitate the understanding and distinction of the Java types, I propose to restrict the name *Pithecanthropus erectus* to all those forms placed in Group 4. The type represented by the giant Sangiran Mandible of 1941, in Group 1, will continue to bear the name *Meganthropus*[2] *palaeojavanicus* given to it by von Koenigswald (according to W. C. B. Koolhoven's letter of October 27, 1941). For Group 2, represented by the brain case and maxilla and referred to *Pithecanthropus* as Skull IV, I propose the name *Pithecanthropus robustus* (see p. 33). The Sangiran Mandible of 1937, designated as *Pithecanthropus* Mandible B, seems to be intermediate between *Pithecanthropus erectus* and *robustus*, but as the differences are slight, and only a fragmentary jaw is known to date, I consider it more appropriate to desist from assigning a special name to this, the sole occupant of Group 3.

So far this survey has referred only to those hominids discovered in the Trinil beds. However, two other fossil hominids are to be considered. One was found in the layers beneath the Trinil beds; the other came from the layers above them. The first is represented only by an infantile calvaria called *Homo modjokertensis* von Koenigswald.[3] The second comprises 11 more or less fragmentary calvaria and one tibia and is called *Homo soloensis* Oppenoorth.[4]

Homo modjokertensis, recovered from the Poetjong beds near Modjokerto in east Java, has been classified by von Koenigswald as a juvenile hominid and referred to the *Pithecanthropus* type as represented by the Trinil skull cap. I questioned the accuracy of this reference,[5] mainly for two reasons. First, I found that although the skull is that of a baby, the parietal bone is longer than the same bone in the adult *Pithecanthropus* Skull I; it is also longer than this bone in Skull II which was found in the meantime. Second, I found that

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[1] Weidenreich, 1943b.

[2] Etymologically, *Megalanthropus* would have been more correct.
[3] Von Koenigswald, 1936.
[4] Oppennoorth, 1932a, 1932b.
[5] Weidenreich, 1938.

the curvature of the occipital bone differed too greatly from that of the adult skull even when difference in age was considered. These facts, I wrote, "are in my opinion incompatible with the assumption of a direct general relation between that baby skull and *Pithecanthropus*," but I added, "so far as the latter is represented by the two adult skulls."[1] Since the publication of this article I have had the opportunity of studying the *Homo modjokertensis* skull. In addition, the whole question appears in a different light when the new finds of *Pithecanthropus robustus* and *Meganthropus* are taken into consideration. It is not my intention to enter into anatomical details in this paper. The description of *Homo modjokertensis* and a discussion of all questions related to it will be the subject of a special publication. Yet this skull cannot be set aside completely, for it helps to clear up certain morphological and geological points involved in the present study.

It is the infantile skull of a hominid, apparently of a primitive one. Its correct classification, however, depends on two factors: on the exact determination of its age and on an accurate knowledge of the kind of transformation such a primitive hominid skull might undergo in the course of its growth from infancy to the adult stage. Von Koenigswald assumed that the skull belonged to an individual about one year old and based his conclusion on the calculation of its height in relation to its length. But the picture changes if the estimate of the age changes. If only the proportions of the brain case can be taken as a basis, as in this case, then the younger the skull, the closer it will approach modern human proportions. For an elaboration of this point the reader is referred to my paper on the brain and its role in the phylogenetic transformation of the human skull.[2] I shall examine this question further in my forthcoming paper, considering whether the *Homo modjokertensis* skull belongs to *Pithecanthropus erectus* (Group 4 of our present classification), to *Pithecanthropus robustus* (Group 2), or even to *Meganthropus* (Group 1). In other words, cannot *Homo modjokertensis* be a member of a more primitive and more ancient group than *Pithecanthropus erectus?*

If this were true, the *Pithecanthropus* problem would be simplified in one respect. The skull of *Homo modjokertensis* was found in the Poetjang beds which contain the Djetis fauna and always underlie the Trinil beds. They are geologically older than the Trinil beds and belong to the Lower Pleistocene period. If the *Homo modjokertensis* skull has not been transported from a more recent horizon into the beds from which it was recovered through later volcanic action (see above), but was really contemporaneous with the fauna of the Poetjang beds, as von Koenigswald[3] and de Terra[4] believe, then *Pithecanthropus* would be the characteristic hominid of the Lower as well as the Middle Pleistocene. It is true that, so far, there is no evidence that *Pithecanthropus robustus* or *Meganthropus* is geologically a more ancient form than *Pithecanthropus erectus* but, as was stated earlier, this possibility exists. Deposition in the Trinil beds does not exclude provenance from older formations underlying them. *Homo modjokertensis* as an infant representative of *Pithecanthropus robustus* or *Meganthropus* would give evidence of the harmony between morphological and geological sequences in human evolution. I shall return to this question in the following section.

Homo soloensis confronts us with another problem. As I have shown in my paper on the *Sinanthropus* skull,[5] *Homo soloensis* represents, morphologically, the next recognizable stage in human evolution with *Pithecanthropus* as the preceding stage and a form like those of the European Neanderthalians as the subsequent one. Of course, in such a case, *Pithecanthropus* is to be understood as *Pithecanthropus erectus* as represented by Group 4. But one remaining point is not quite satisfactorily explained. The *Homo soloensis* skulls differ from *Pithecanthropus* Skulls I and II in some characteristic features: 1, all are very large, considerably exceeding the *Pithecanthropus* skulls in length (193–215.5 mm. in the first case, 176.5 and 183 mm. in the latter); 2, the occipital torus is very pronounced, as are the muscular impressions of the nuchal plane; 3, the mastoid process is large and projects far downward. All these peculiarities are in contrast to the condition of *Pithecanthropus* Skulls I and II. A possible explanation of

[1] Weidenreich, 1937b.
[2] Weidenreich, 1941b.

[3] Von Koenigswald, 1936.
[4] De Terra, H., 1943b.
[5] Weidenreich, 1943b.

these differences is that they may be sexual. In that case the two *Pithecanthropus* skulls were females and all the *Homo soloensis* skulls males, regardless of the apparent differences among the latter. On this theory, however, it is difficult to comprehend why the increase of the size of the brain (from about 900 cc. in *Pithecanthropus* to an average of 1100 cc. in *Homo soloensis*) was accompanied by such an increase of superstructures of the brain case when their decrease might be expected.[1] These conflicts would be eliminated if the immediate ancestor of *Homo*

[1] Weidenreich, 1941b.

soloensis had a much larger and more massive skull with much heavier superstructures than the two *Pithecanthropus* Skulls I and II. Later I shall return to the question as to whether types such as *Pithecanthropus robustus* or *Meganthropus* could be regarded as ancestral to *Homo soloensis*. But before we discuss the general problems raised by the discovery of the giant hominids, we must form an approximate idea of their size and to what extent we can draw conclusions from the size of mandible and teeth as to the massiveness and size of the entire body of the individual.

VII. *GIGANTOPITHECUS*, *MEGANTHROPUS*, AND *PITHECANTHROPUS*

OF THE LARGEST TYPE, *Gigantopithecus*, only the third lower molar and the first or second upper molar are known. The first step, therefore, is to calculate from these teeth the size of the other molars and teeth and then the size of the mandible which contained them. As stated above, the third lower molar is longer than the first and second molars. Since the same conditions are found in *Pithecanthropus* Mandible B, the length of the missing M_1 and M_2 can be computed on the assumption that the ratio between the length of M_3 and that of M_1 and M_2, respectively, was the same in *Gigantopithecus* as it is in *Pithecanthropus*. The result of these calculations is presented in Table 16. The length of the row of the three lower molars in *Gigantopithecus* probably was 60.9 mm. This length is 52 per cent more than the row in *Pithecanthropus* Mandible B. In *Meganthropus* only M_1 is preserved. Again using the three molars of Mandible B as a basis, the length of the two missing molars and that of the molar row in *Meganthropus* can be computed (see Table 16) as amounting to 48.6 mm. This is 21.5 per cent more than the *Pithecanthropus* row and 20.2 per cent less than the *Gigantopithecus* row.

The minimum breadth of the ascending ramus of the mandible can be calculated from the length of the molar row. In the Heidelberg mandible the molars have a length of 36 mm., while the breadth of the ramus is 51 mm. The ratio between the length of the molars and the breadth of the ramus, therefore, is 7:10. In *Sinanthropus* G I the molar length is 38.5 mm., and the breadth of the ramus is 42 mm. In this case, then, the ratio of molar length to ramus breadth is 9.2:10. In *Sinanthropus* H I the molar length is 32 mm., and the breadth of the ramus is 40.0 mm. The ratio, therefore, is 8:10. In modern man the average of the molar length is 33 mm., and the average of the ramus breadth is 35 mm.[1] The ratio is 9.45:10. In the hominids, therefore, the ratio shows a tendency to increase, ranging from 7:10 in the Heidelberg jaw to 9.45:10 in modern man. In male gorilla the length of the three molars is 51 mm., and the

[1] Martin, 1928.

breadth of the ramus 80 mm. The ratio is 6.4:10. In male orang-utan the length of the molar row is 47 mm., and the breadth of the ramus is 65 mm.; the ratio is 7.2:10. In male chimpanzee the ratio is 6.9:10 (33:48). In anthropoids, therefore, the ratio is smaller than in hominids, ranging from 6.4:10 to 7.2:10. In the female pygmy chimpanzee (*Pan paniscus*), the length of the molar row is 28.2 mm., and the least breadth of the ramus is 30 mm. In the normal-sized female chimpanzee (*Pan schweinfurthi*) the corresponding measurements are 34.0 mm. and 42.5 mm. The "anthropoid average" is about 6.8:10. The "hominid average" is about 8.4:10. If the latter ratio is taken as the basis, the least breadth of the ramus of *Meganthropus* would total 58 mm. and that of *Gigantopithecus* 73 mm. If the anthropoid ratio is used, the respective figures are 71 mm. and 89 mm. The average of these figures is 65 mm. for *Meganthropus* and 80 mm. for *Gigantopithecus*.

The length of the mandible, the distance between the incision and the median point of a plane laid through the two gonia, is difficult to compute. If the above figures are taken as a base, the length of the *Meganthropus* mandible is about 135 mm. and that of the *Gigantopithecus* about 180 mm. The former measurement corresponds to about the length of the mandible of a male orang-utan, the latter to that of a male gorilla. The length of the mandible of modern man is between 85 and 100 mm. That of the Heidelberg mandible is 109 mm. and that of *Sinanthropus* (Mandible H I) is 100 mm. But there is an important difference in hominids and anthropoids which must not be overlooked when the dimensions of the mandibles are compared. In anthropoids there is a pronounced prognathism, that is to say, the lacteal portion of the dental arch is much longer than in hominids. For, in anthropoids, not only the two premolars but the canine is longer than the corresponding teeth in hominids, and these are arranged in a straight longitudinal line, together with the molars, thus adding to the "length" of the mandible. In hominids, however, as in *Meganthropus*—and supposedly in *Gigantopithecus*—the premolars are much short-

er, and the canine has moved around the corner into the frontal line. In other words, the snout has been considerably shortened. Therefore, in hominids the section of the length of the body of the mandible is smaller in proportion to the ramus than it is in anthropoids.

Two other dimensions of the mandible, the height and thickness of the body, can be estimated on the basis of the size of the teeth. There is, of course, no fixed correlation between size of the teeth and strength of the jaw, as I have shown in an earlier paper.[1] There I discussed this problem with reference to the Heidelberg mandible with its apparent disproportion between the size of teeth and bone, the former

ness at the same level about 30 mm. These calculations, however, do not take into account the dimensions of the *Meganthropus* mandible which is higher and thicker than any other hominid mandible. In this case the calculation can be based only on the length of the lower molar row, as computed from M_1. The values obtained in this way are slightly higher, namely, 55 mm. for the height and 34 mm. for the thickness. The *Gigantopithecus* mandible is, therefore, 75 per cent higher and 100 per cent thicker than the average mandible of modern man. The differences in height and thickness between the smallest and the largest type of hominid mandible are far less significant than similar

TABLE 18

CALCULATION OF THE SIZE OF THE MANDIBLE OF *Gigantopithecus* ON THE BASIS OF THE HEIGHT OF THE POSTERIOR ROOT
OF M_3 (IN MILLIMETERS)

Measurements	Giganto-pithecus	Megan-thropus	Pithecan-thropus Mandible B	Sinan-thropus Mandible G I	Heidel-berg	Modern Man	Gorilla	Orang-utan	Chim-panzee
Height of the root	23.7	c. 20.6	15 ?	15.5	14.5	12.9	16.9	17.7	11.6
Height of the mandible between M_2 and M_3	c. 50.2	45.0	31	32.8	31.0	23.7	38	39	26.3
Thickness of the mandible between M_2 and M_3	c. 31.0	26.3	17.8	19.6	21.4	16.3	24.7	21.3	17.3

being very small when compared with the massiveness of the latter. Nevertheless, it is evident that enormous teeth, like those of *Gigantopithecus*, must have been set in correspondingly big jaws. The best available guide in making such a calculation is the height of the posterior root of the third lower molar of *Gigantopithecus*. The height of this root is 23 mm. When the average ratio between height of the root and height and thickness of the mandible, as computed in Table 18, is taken as a basis, the height of the *Gigantopithecus* mandible between M_2 and M_3 is 49.7 mm., and its thickness at the same level is 29.3 mm. When the length of the molar row is taken as a basis, the corresponding figures are 52.4 and 31.4 mm., that is, the result is about the same.

The length of the *Gigantopithecus* mandible would, therefore, be about 180 mm., its height at the molar level about 50 mm., and its thick-

[1] Weidenreich, 1934.

differences, for instance, in dwarf and giant types of Felidae. When the correlation between the carnassial tooth of a lion and length and thickness of the mandible is compared with that of a wildcat, the lion tooth is found to be three times longer, but the mandible is five times higher and four times thicker. In the normal-sized type of chimpanzee the lower molar row is about 25 per cent longer than that of the pygmy, but the height of the mandible is 40 per cent greater and its thickness 20 per cent greater. The chimpanzee example shows that there is also a correlation between the measurements under discussion in anthropoids of the same type. But the ratios obtained in this case cannot be applied to the extremes of *Gigantopithecus*, on one hand, and modern man, on the other, for these two hominids are much more variant in size than pygmy and normal-sized chimpanzees.

A mandible about double the size of that of

modern man requires a maxilla of approximate dimensions. The total facial height (nasion-gnathion) of *Gigantopithecus* can be calculated on the basis of the symphyseal height of the mandibula. If the height of the body of the mandibula, measured between M_2 and M_3, is 50 mm. (see p. 108), then the symphyseal height (incision-gnathion) is about 60 mm. The heights of the crowns of the upper and lower incisors were certainly greater than those of the upper and lower molars (12.4+12.5 = 24.9 mm.) and may have been 30 mm. The distance from prosthion to gnathion, therefore, is about 90 mm. In modern man the prosthion-gnathion height of the face is about 40 per cent of the total facial height. If the same ratio is applied to *Gigantopithecus*, his total facial height would be 225 mm., which is nearly double the facial height of a modern man. *Meganthropus*, with a symphyseal height of 50 mm. and a height of 70 mm. for the prosthion-gnathion distance, had a total facial height of 175 mm. The breadth of the mandible, as represented by the bicondylar and the bigonial breadths, was certainly not double that of modern man. The most that can be conceded for the bicondylar breadth is 170 mm. for *Gigantopithecus* and 150 mm. for *Meganthropus* against an average of 120 mm. in modern man.

There are no specific indications as to the size of the brain case, but since there is a definite correlation between its size and that of the jaws,[1] it can be assumed that the capacity of the *Gigantopithecus* brain case was not over 800 to 900 cc. if, indeed, it reached this volume. But, as a consequence of the size of the jaws, there must have been tremendously large and heavy superstructures, and the walls of the brain case itself must have been very thick. When we realize that the cranial wall of the much smaller skull of *Pithecanthropus robustus* was about double the thickness of that of modern man,[2] we get a clearer picture of what must have been the appearance of the skull of *Gigantopithecus*. There must have been enormous frontal and occipital tori. But there is no evidence that there was a sagittal crest, such as characterized male gorilla and orang-utan; the space available for the attachment of the temporal muscle was probably large enough considering the extent of the brain case proper.

[1] Weidenreich, 1941b.
[2] Weidenreich, 1943b.

Nevertheless, the possibility that such a crest was developed cannot be entirely neglected. The skull of *Pithecanthropus robustus* is crowned by a chain of isolated knobs set along the obelion region. These belong to the reinforcement system and in addition to the sagittal crest may have been present in both *Gigantopithecus* and *Meganthropus*.

The assumed relatively small size of the brain case makes it difficult to estimate the size of the entire skull. As a whole, it was certainly not double that of modern man, but as the jaws are essential skeletal parts of the face, it may have been double the height of that in modern man. Even with the limitation to the size of the face, it can be stated that *Gigantopithecus* had a skull which far exceeded the dimensions of the largest male gorilla recorded.

But we are completely in the dark when we try to estimate the stature of the giant hominid. The stature of the gorilla is not so great as would be expected from the size of the skull and the length of the trunk. The disproportion is, of course, due to the shortness of the leg bones, particularly of the femur. According to A. H. Schultz,[3] the height of the body of a male gorilla (recumbent position) is about the same as that of man (1708 mm. against 1704 mm.). But the total length of the lower limb is much less, the difference being in the femur. The measurements are: lower limb, 782 mm. in *Gorilla gorilla*, 793 mm. in *G. beringei*, 882 mm. in modern man; femur, 376 mm.[4] in gorilla, 429 mm. in Mongols.[5] Unfortunately, there is no direct evidence as to the height of the lower extremity of either *Gigantopithecus* or *Meganthropus*. Since, however, these were both hominids, they must have followed the hominid pattern; therefore, they had a long, not a short, femur. In my paper on the limb bones of *Sinanthropus*,[6] I was able to prove that the *Sinanthropus* femur was typically human in all its characteristic features: length, proportion, and form. From this fact can be deduced first, that *Sinanthropus* already had an erect posture, and second, that the adoption of erect posture preceded the transformation of the skull into its definite human form. That this is equally true for *Pithecanthropus*, or at least for *Pithecan-*

[3] Schultz, 1933, 1937.
[4] Schultz, 1937.
[5] Weidenreich, 1941a.
[6] Weidenreich, 1941a.

thropus robustus, is made clear by the position of the occipital foramen. In my papers on the *Sinanthropus* limb bones[1] and the skull,[2] I made two points concerning this foramen. The occipital foramen of *Pithecanthropus robustus* was even more centrally located than that of *Sinanthropus* (see the preceding section dealing with *Pithecanthropus robustus*). There is no indication that this foramen in any one of the known fossil hominids is placed so much to the rear that it approaches the position of the occipital foramen of anthropoids. This fact, together with the human characteristics of the *Sinan-*

only 455 mm.[3] Second, Femur II is very slender. Its length-thickness index is only 16.9, while that of the Trinil femur was 20.0. Two conclusions can be drawn from these facts. First, the two creatures to whom the femora belonged were tall. The stature of the individual to whom the Trinil femur belonged was 1680 mm. (5 feet, 6⅛ inches) and the stature of individual of Femur II, 1780 mm. (5 feet, 10⅛ inches). (The stature of *Sinanthropus* was only 1560 mm. or 5 feet, 1½ inches.) Second, there were some differences in size. Considering the questionable nature of the Leiden femora, too much impor-

TABLE 19

Some Measurements of the Skeleton of *Megaladapis edwardsi* Compared with *Nycticebus* (in millimeters)
(Figures of *Megaladapis* taken from Lorenz von Liburnau, 1905)

Measurements	Nycticebus A.M.N.H. No. 90381	Megaladapis	Ratio	Giant Lemur Larger Than Dwarf Lemur
Length of the row of the lower molars	9.8	79	1:12.4	c. 8X
Maximum length of the mandible	34.5	238	1:14.5	c. 7X
Height of the body of the mandible at M₂	6.4	42	1:15.2	c. 7X
Thickness of the mandible at M₂	3.3	25	1:13.3	c. 7X
Length of the skull from the posterior end of the occipital condyles to the tip of the nasal bones	53.0	288	1:18.4	c. 5X
Bijugular breadth	38.5	150	1:25.6	c. 4X
Height of the brain case without crista sagittalis	25.5	63	1:40.4	c. 2.5X
Maximum breadth of the sacral bone	12.1	112	1:10.7	c. 9X
Length of the femur	69.8	227.5	1:30.7	c. 3.3X
Thickness of the femur shaft	4.1	22	1:18.6	c. 5X
Length of the humerus	59.0	248	1:24.0	c. 4X
Breadth of the humerus	85.4	29.5	1:18.3	c. 5X

thropus femur, indicates that we may expect erect posture and, therefore, the same characteristics of the femur in the giant hominids.

This problem of posture compels us to revert again to Dubois' original femur found in the Trinil beds, and to those other five femora, forgotten for so many years in Leiden, but allegedly from the same horizon. Femur II of the later specimens differs remarkably from the original Trinil femur in two main characteristics. First, it is much longer than the Trinil femur, although its maximum length can only be estimated because the distal end is missing. But, judging from the portion available, the maximum length cannot have been less than 500 mm.; the length of the Trinil femur was

[1] Weidenreich, 1941a.
[2] Weidenreich, 1943b.

tance must not be attached to data secured from them. Nevertheless, they seem to indicate that Java had a population of tall stature and that this population may have been related in some way to the early giant hominids.

Since all direct indication as to the stature of *Gigantopithecus* and *Meganthropus* is lacking, we are forced to hunt for analogies to discover whether jaws and skulls of gigantic size are necessarily combined with gigantic bodies. The best example is afforded, within the primate order itself, by *Megaladapis*, the giant lemur of the Pleistocene of Madagascar. This, however, was a climbing primate, probably one which climbed slowly, and which had a short femur and a long humerus. *Megaladapis* can best be compared with *Nycticebus* of today which has

[3] Weidenreich, 1941a.

the same locomotor habits. Although the length of the row of lower molars in *Megaladapis* is eight times that of the molar row in *Nycticebus* (Table 19), the length of the skull is only five times as great, while the femur is little more than three times longer. These figures do not, however, offer any precise hint as to the body size of *Gigantopithecus* compared with that of modern man, for there is no ratio of general validity. If the height of the brain case is disregarded, the low ratio is due to the well-known fact that giant types have relatively smaller brain cases than dwarf types[1]; the ratio varies from 1:30.7 to 1:12.4. In *Gigantopithecus* the length of the lower molar row is only twice that

[1] Weidenreich, 1941b.

of modern man, not eight times, as in the lemur example. When the dimensions for the femur are calculated on the basis of the lemur ratio for the femur and the hominid ratio for the length of the molar row, the *Gigantopithecus* femur proves to be little longer than the femur of modern man and only slightly thicker. The same holds true for *Meganthropus*.

Therefore, we can dismiss the body dimensions of the giant hominids, *Gigantopithecus* and *Meganthropus*, with the very general statement that they must have had large, heavy, and massive skulls, large strong trunks, but only slightly longer and stronger leg bones. No more precise statement can be made.

VIII. THE GIANT HOMINIDS AND THEIR BEARING ON THE PROBLEM OF HUMAN EVOLUTION

A. RELATIONSHIPS BETWEEN *MEGANTHROPUS, GIGANTOPITHECUS,* AND *PITHE-CANTHROPUS,* AND BETWEEN *SINANTHROPUS* AND *PITHECANTHROPUS*

DOUBTLESS BOTH *Meganthropus* and *Giganto-pithecus* attained gigantic dimensions, the latter being larger than the former, which was already enormous. This statement immediately suggests several questions: 1, Are these giant hominids ancestral to modern man, as a rule? 2, Have they given origin only to a certain group (race) of modern man? 3, Must they be regarded as mere "specializations," side branches of the main stem of the hominids? Although the basis for a precise answer to these questions is very limited because of the scarcity and defectiveness of the available fossil material, we are able to draw some conclusions which may at least serve as guiding lines for further research and investigation.

In a previous section, when discussing the *Pithecanthropus* problem, I called attention to the fact that the mandible specimens recovered from the Trinil beds of Java form a continuous line leading from the smaller to the larger hominid forms. This line is as follows: Kedung Brubus→*Pithecanthropus* Mandible B→*Pithe-canthropus robustus* (mandible unknown)→*Meganthropus;* or, with reference to the skull caps: *Pithecanthropus* Skull II and Dubois' skull cap (Skull I)→*Pithecanthropus robustus* (Skull IV)→*Meganthropus* (calvaria unknown). I reiterate that difference in size due to sex may be dismissed, since we are dealing certainly with three, and possibly even four, types of sizes. To classify these as only two types, namely, male and female, would necessitate the extension of the minimum-maximum values of size, either for males or females, far beyond any range now known. In addition, there are morphological facts, as I have stated—characters of teeth, mandibles, and skull cap—which prove close relationship between the different types. Their relationship can be of a genetic nature, one form deriving from the other, or all can represent the same evolutionary stage but vary in size from dwarfs to giants like modern domesticated dogs. In the first case, the difference in size must be accompanied by corresponding primitive and advanced features, respectively. In the latter, all forms,

small and large alike, must be uniform with regard to those features affected by evolutionary changes. It is easy to show that the first alternative is correct, although the test subjects available for comparison are not the same for each type. Skulls I and II of *Pithecanthropus erectus,* in spite of the considerable thickness of their walls, are more delicate than the skull of *Pithecanthropus robustus.* Their sagittal crests do not consist of isolated knobs; their occipital tori are much less developed; their brain cases are higher, narrower at the base, and more expanded laterally above the base. The mandible of *Meganthropus* is not merely more massive than the *Pithecanthropus* Mandible B, but shows almost no differentiation of its buccal surface, and its digastric fossa has quite a different location. *Pithecanthropus erectus, Pithe-canthropus robustus,* and *Meganthropus palaeo-javanicus* are, therefore, three different types. The third represents the most primitive form; the first the most advanced form; and the second an intermediate form.

I am fully aware that the geological data, so far, do not lend support to this assumption. All three types, *Meganthropus, Pithecanthropus robustus,* and *Pithecanthropus erectus,* were recovered from the same stratum, the Trinil beds, which are considered a uniform Middle Pleistocene formation. But since all the specimens found in this bed are in secondary deposits, and since the character of the formation indicates that the soil may have been disturbed by mud torrents, not once but repeatedly, the possibility does exist that the specimens came from different geological horizons, both older and more recent. But even if this were not true and the three types are really contemporaneous, it would not make a fundamental difference. Morphologically, we are dealing with forms which differ from one another more than any known fossil or human types, whether they lived in the same territory or were spread over a much larger area. Therefore, the range of variation appears much greater than that usually observed. But since all these variations constitute a phylogenetic line, we have before

us a hominid type in the very process of evolution; this evolution may have taken place in the same territory and during a short period of time. From this statement, it follows that I regard the giant *Meganthropus* as the most primitive form which gave origin to the more advanced, smaller ones. If this is true (for more precise structural details see the next section), early giant hominids must have preceded the smaller ones.

So far I have not referred to *Gigantopithecus*. This hominid form exceeds the already enormous *Meganthropus* in size. Regarded from the morphological viewpoint, it is also more primitive. This point is proved by: 1, the extraordinary length of the third lower molar; 2, the fact that the trigonid is considerably broader than the talonid; 3, the marked *Dryopithecus* pattern; and 4, the fact that the well-developed roots do not reveal any sign of fusion or reduction. *Gigantopithecus* may well be an ancestral form of *Meganthropus*, although there is no evidence of its presence in Java. Yet, as I said before, *Gigantopithecus* very probably belongs to the "yellow deposits" of the South China caves. There it is the hominid member of the characteristic Middle Pleistocene fauna which is closely related to the Upper Siwalik fauna of India,[1] and is distributed from India through Burma, into the East Indian islands and for this reason was designated by von Koenigswald[2] as the "Sino-Malayan fauna." So far, we have no knowledge of giant hominids among the Siwalik fauna of India. But giant anthropoids were present there, as is evidenced by *Dryopithecus giganteus* and similar forms of varying size. So it may well be that *Gigantopithecus* originated in India. Whether or not this is true, it is reasonable to assume that the southeast Asiatic mainland, in Lower or Middle Pleistocene time, was the habitat of a giant hominid and that, as the whole fauna spread to the East Indian islands, this hominid (*Gigantopithecus* or one of its immediate descendants) also migrated to Java, where it underwent a general transformation into hominid forms, at once more advanced and smaller. The chart (Fig. 27), partly taken from Colbert,[3] shows the probable route the fauna followed on the road to Java.

There may be one objection to this theory. *Gigantopithecus*, like *Meganthropus* and the *Pithecanthropus* forms, belonged to the Middle Pleistocene. But Teilhard and others[4] as well as Pei[5] left open the question as to whether the "yellow deposits" of South China, with their embedded fauna, are Lower or Middle Pleistocene. On the other hand, the baby skull of *Homo modjokertensis*, which belongs to the *Pithecanthropus* group, was recovered from the Djetis bed which, according to von Koenigswald,[6] H. de Terra,[7] and Colbert,[8] is Lower Pleistocene. In any case, so long as we do not know the precise geological horizon to which the different forms in question are to be attributed, their relationship to each other as ancestor and descendant cannot be fixed. On the other hand, an ancestral form must not necessarily disappear completely after giving rise to a new type. On the contrary, there is evidence in the ancestry of the horse[9] that the original type can survive and be contemporary with the following evolutionary stage. This would be all the more probable if ancestors and descendants had different habitats—in this case South China and Java.

Now we come to the question of gigantism. Is the development of gigantism a more or less local and accidental event? Is its occurrence to be compared with the occasional occurrence of giant and dwarf types among mammalian groups in times past or present? Did man derive from a giant anthropoid or pass through a giant stage during his evolution? In my paper on the *Sinanthropus* skull[10] I arrived at the following conclusions:

The architectonic framework of the *Sinanthropus* calvaria appears to be only a special differentiation within the general massiveness of the cranial bones. If the thickness is expressed by an average index giving the mean of the measurements of the four chief bones of the vault: frontal, parietal, temporal and occipital bones, this index stands at 9.7 mm. *Pithecanthropus* has bones even thicker and its index totals 10.0. The Ngondang skull, for which no exact figures are available, is not inferior to *Pithecanthropus*. The Neanderthalians, with the Rhodesian skull

[1] Colbert, 1943.
[2] Von Koenigswald, 1938, 1939.
[3] Colbert, 1943.

[4] Teilhard de Chardin, Young, Pei, and Chang, 1935.
[5] Pei, 1935b.
[6] Von Koenigswald, 1936.
[7] De Terra, H., 1943b.
[8] Colbert, 1943.
[9] Matthew, 1926.
[10] Weidenreich, 1943b.
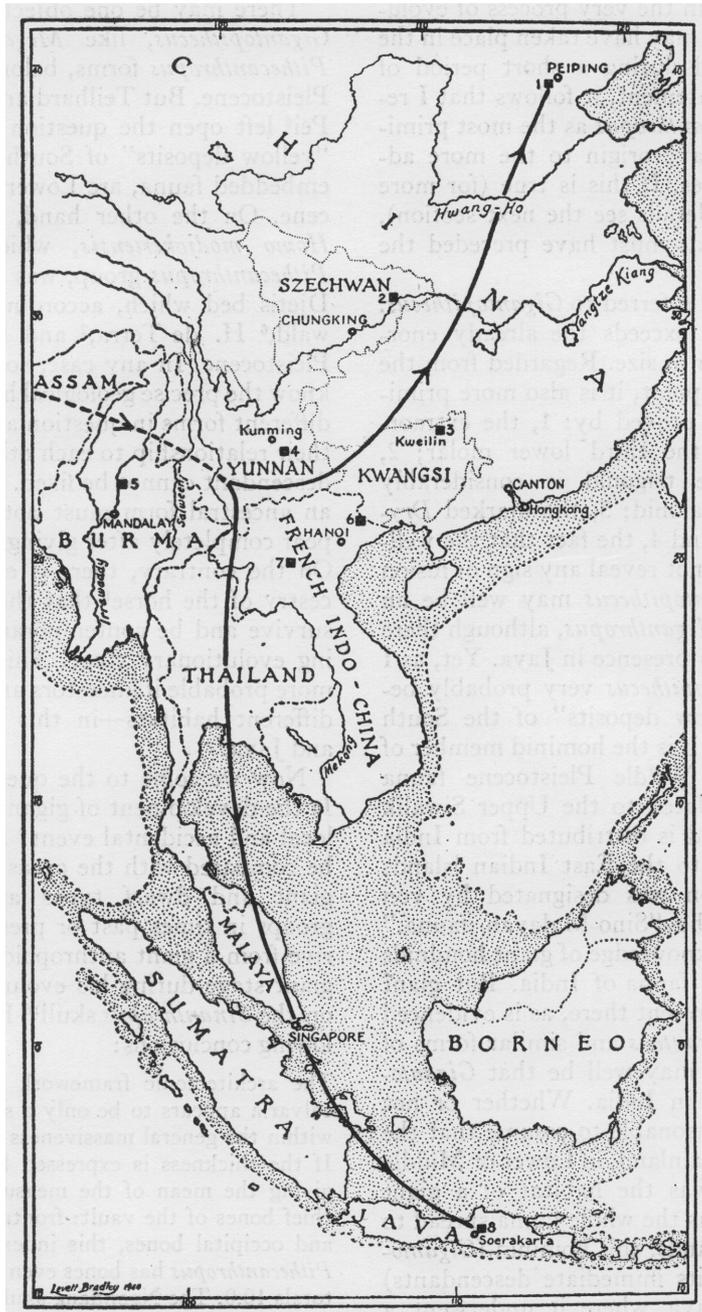
Fɪɢ. 27. Map of southeast Asia and Indonesia showing the distribution of the Sino-Malayan fauna.

excelling others, have an index of 7.2, while modern man closes the list with an index of 5.2, that is to say, about half the thickness of *Pithecanthropus*. There is, therefore, a gradual reduction in the index from primitive stages to modern man, a condition which conforms perfectly with the reduction of strength and the extension of the architectonic framework.

The long bones of *Sinanthropus*, femur and humerus, show the same peculiarity, the medul-

lary canal being much narrower than in modern man, while the wall is correspondingly much thicker. In a transverse section through the shaft of the *Sinanthropus* femur, the space occupied by the canal is one tenth of the surface against nine tenths of the wall, while the respective figures in modern man are one quarter and three quarters. That this massiveness of bone was not restricted to skull and limbs, but was also a quality of the mandible, has been shown by the discovery of *Meganthropus*. This characteristic feature of the early hominid forms which disappears in the course of human evolution can be understood only as an inheritance from an ancestral form in which the massiveness was probably still more pronounced. The fact that *Pithecanthropus robustus*, the more primitive form, exceeds *Pithecanthropus erectus*, the more advanced form, in massiveness points in this same direction.

The thickness of the *Gigantopithecus* jaw can only be estimated on the basis of the tooth size. However uncertain such a calculation may be, no doubt the jaw was considerably thicker than the *Meganthropus* mandible. These huge dimensions require a correspondingly gigantic body.

An assumption of gigantic forerunners of modern man would explain satisfactorily the occasional occurrence of abnormally large forms in later stages of evolution, such as the *Homo soloensis* skulls, the Rhodesian skull, the Wadjak skull, and the Heidelberg mandible. The wide spread of these forms indicates, it seems to me, that the development of early giant hominids was not restricted to southeast Asia and the East Indian islands, but was a characteristic feature of early man wherever he may have lived. The fact that such forms are completely unknown from other regions of Asia, Europe, or Africa does not mean much in this case. All the remains of fossil hominids originating in those places represent types morphologically advanced, and none of them go further back than the Neanderthal stage of evolution. The only reference to the existence of early giant hominids in Europe has been made by W. Freudenberg.[1] In several publications he described fragments of bones which were occasionally found in sand pits of the Elsenz Valley near the locality where the Heidelberg mandible was found. He attributed

the fragments to either hominids or hominid-like apes and classified them under such names as *Gigantanthropus, Hemianthropus osborni, Homo* cf. *heidelbergensis, Postpliopithecus hominoides*. All the fragments are either too small or too fragmentary for a diagnosis of their anatomical character, so that no decision as to the type to which they may have belonged can be risked. Freudenberg did not share such belief, as at least one of his papers shows.[2] In this he described the fragment of a long bone as a juvenile femur of a primate which he called *Postpliopithecus hominoides*. However, the photographs and skiagram which illustrate the paper reveal that the alleged primate femur is very likely the ulna of a bird. Another fragment considered by Freudenberg as a portion of the axillary margin of the scapula of *Homo heidelbergensis* is probably also a bird bone, judging from the character of the exposed cancellous tissue. It may possibly be a portion of the carina, but it does not seem to be a mammal bone, and most certainly it is not the bone of a hominid. Therefore, more convincing evidence of the existence of giant hominids in the Elsenz Valley must be offered than is presented by Freudenberg. On the other hand, we have a very good example of a large primate existing in Europe in very early times and of dwarf forms of the same family living today in South Asia, in the same region as that which the *Pithecanthropus* group inhabited. I am referring to the *Paedopithex rhenanus* from the Lower Pliocene of Eppelsheim, basin of Mayence, Germany. It is true that only the femur has been preserved, but that is enough to show that this form was a typical gibbon, differing only in size from the forms now living.[3] The length of the femur of the smallest living gibbons, *Hylobates klossi*, is about two thirds that of the Pliocene form and the circumference of the shaft little more than half of it (length, 286 mm. compared with 188 mm.; circumference, 58 mm. compared with 33 mm.). So it may well be that, some day, the bones of giant hominids will also come to light from the Pliocene of Europe.

The fact that small hominid forms such as *Pithecanthropus erectus* were found with giant forms raises another question. Is it possible that small and large hominids lived side by side

[1] Freudenberg, 1929, 1931, 1938.

[2] Freudenberg, 1929.
[3] Gieseler, 1926.

just as pygmy and normal-sized human racial groups do today in Malaya, in New Guinea, in the Philippines, and in Central and East Africa? And is it not possible that such differentiation in size has accompanied the entire line of human evolution? *Sinanthropus pekinensis* shows a great variation in the size of the skulls.[1] Unfortunately, the largest skull (Skull V) and the smallest one (Skull VI) are represented only by fragments. Yet, from the size of the squama of the temporal bone, preserved in each case, we can deduce that the cranial capacity of the first must have been half again larger than that of the second. The differences in size of the upper canines of *Sinanthropus* are correspondingly great.[2] Tooth No. 16 is 10.5 mm. long and 10.4 mm. broad; tooth No. 15 is 9.1 mm. long and 9.8 mm. broad. I attributed the larger canine to a male and the smaller one to a female. It may well be that this identification is correct, but, considering the great differences in size within the *Pithecanthropus* group, I cannot completely dismiss the idea that, in addition to sex differentiation, differences in size may also be due to a certain degree of gigantism in *Sinanthropus*.

More important than this question, which cannot be answered so long as the material available is so meager, is the question concerning the relation between the Java and South China giants and their relations to other early hominids, particularly to *Sinanthropus*. For morphological reasons I maintain the opinion that *Pithecanthropus erectus* [as represented by the Trinil skull cap (I)], the Sangiran skull cap (II), and Mandible B, and *Sinanthropus*, are representatives of the same stage of human evolution. I interpret their differences, the existence of which cannot be denied, as the equivalents of racial differentiations occurring among modern mankind.

Ashley-Montagu,[3] in a recent paper on the occurrence of the maxillary diastema in anthropoids and man, refers also to *Pithecanthropus* and his relationship to *Sinanthropus*. He objects to my interpretation, for, he writes,

The fact that *Pithecanthropus* IV was characterized by a large premaxillary space whereas *Sinanthropus* has no space at all ... would certainly separate these two forms into, at least, two distinct genera, and certainly renders Weidenreich's statement that

"the differences are not greater than those found among the different races of present mankind" quite unacceptable.

When Ashley-Montagu wrote this sentence, he was apparently completely unaware that in the preceding pages of the same paper he himself noted the absence of maxillary diastema in the adult female orang-utan in three of 20 cases or in 15 per cent. Selenka[4] found maxillary diastemas less than 1 mm. broad, that is, virtually missing, in 30 per cent of the adult female orang-utans, while Remane[5] found them less than 1 mm. broad in 4 per cent of the adult males. Since only absence or presence of the maxillary diastema is considered by Ashley-Montagu as a sufficient distinction to assign two specimens to two different genera, I wonder why he did not split *Pongo pygmaeus* or, at least, the *Pongo* females into two different genera. We know from Remane's interpretation that the breadth of the maxillary diastema varies from 16 mm. to 1–2 mm. in male gorillas, from 11 mm. to nil in male orang-utans, from 11 mm. to 1–2 mm. in male chimpanzees, and from 6 mm. to nil in gibbons. Maxillary diastemas one or more millimeters wide occur even in modern man. The tendency to close the gap between the canine and the incisor is apparent, therefore, even in modern anthropoids.

I have shown in this paper why I consider *Pithecanthropus robustus* (Skull IV) a representative of a more primitive form than *Pithecanthropus erectus*. My equating of *Pithecanthropus* and *Sinanthropus* referred to, and still refers, only to *Pithecanthropus erectus* (Skulls I and II). Although *Pithecanthropus robustus* is more primitive than *Sinanthropus*, a characterization which is not based solely on the existence of one indefinite feature (diastema), but on several others, I consider the differences not fundamental enough to separate the two forms "generically" from each other in the sense of the taxonomists and geneticists. I would not be surprised if, one day, we were to encounter a *Pithecanthropus* maxilla without a diastema which may fit, in size and form, the *Pithecanthropus* Skulls I and II.

In any case, the discovery of the skull and maxilla of *Pithecanthropus robustus* (Skull IV) with their surprisingly primitive features, the

[1] Weidenreich, 1943b.
[2] Weidenreich, 1937a.
[3] Ashley-Montagu, 1943.

[4] Selenka, 1898.
[5] Remane, 1921.

finding of a new gigantic primitive hominid (*Meganthropus*) in Java, and, finally, the recognition of *Gigantopithecus* as a true hominid and a member of the Sino-Malayan fauna shed new light on the whole problem. There is no special reason to recapitulate any opinion advanced before these latter conditions were known; formerly we could have only vague ideas as to the kind of relationship between *Pithecanthropus* and *Sinanthropus*. Davidson Black, Teilhard de Chardin, C. C. Young, and W. C. Pei[1] put the question: "In the early Pleistocene what connections, if any, existed between Trinil and Choukoutien?" But the answer was very indefinite. They admit that at this period "some faunistic interchange" between North China and the south "certainly" occurred. They continue:

The situation provides no sound argument for a southern derivation of the progressive northern hominid, *Sinanthropus*, from his contemporary southern relative, *Pithecanthropus*, since the latter was provided with a dentition much too highly specialized to have been ancestral to that of *Sinanthropus*. By no effort of the imagination could one derive a generalized molar tooth such as that of *Sinanthropus* from the highly specialized *Pithecanthropus* type.

In other words Black, the author of this passage, did not believe that *Sinanthropus* came from the south as a descendant of a *Pithecanthropus* type. When this statement was made, no other *Sinanthropus* molars were known except molar No. 34 to which Black has devoted a special paper. The *Pithecanthropus* molars to which he refers are the two molars of Trinil which Dubois attributed to *Pithecanthropus*. We know now, however (see p. 98), that these Trinil teeth are really orang-utan molars. The true *Pithecanthropus* teeth are shown in Mandible B or in the maxilla of *Pithecanthropus robustus* and are rather less specialized than those of *Sinanthropus*. The dentition of *Sinanthropus* is well known, while there are still wide gaps in our knowledge of the dentition of *Pithecanthropus erectus* and *robustus*, of *Meganthropus*, and of *Gigantopithecus*. Therefore, the following statement cannot be extended to all the members of this group, but, without great risk of exposing oneself to revocation by future discoveries, it can be said that some features of the

forms of Java and South China are more basically primitive than those found in *Sinanthropus*: 1, the third lower molars are very well developed and do not reveal any reduction; 2, the second molars, upper as well as lower, are larger than the first ones. On the other hand, the remnants of the cingulum are more distinct in *Sinanthropus*, and the same seems to be true of the wrinkle system of the molars.

If the characteristics of mandible and brain case are also taken into account, there is no difficulty in tracing *Sinanthropus* back to an ancestral form such as *Meganthropus* and *Gigantopithecus*, from which *Pithecanthropus robustus* and *Pithecanthropus erectus* may have originated. This common ancestral form may have been located in South China or, earlier, in India (Fig. 27). While *Pithecanthropus* migrated to the southeast (East Indian islands), *Sinanthropus* turned to the northeast. So far, no forms intermediate between *Gigantopithecus* and *Sinanthropus* have been discovered, nor have we evidence of early hominid forms from China more advanced than *Sinanthropus* proper. But there are weighty reasons for the assumption that the latter did ultimately give origin to certain groups of Mongols.[2] In *Pithecanthropus* some of the subsequent evolutionary stages are known. *Pithecanthropus* gave origin to *Homo soloensis*[3]; in addition, there are indications that this type has been further transformed, through forms like that of Wadjak man, into the recent Australians and Melanesians. This whole transformation may have taken place during Pleistocene time in the East Indies and farther southeastward. Other indications point also to an early connection of the *Pithecanthropus-Homo soloensis* group with Rhodesian man.[4] Future discoveries will show how far these assumptions are correct.

In any case, my earlier studies on the phylogenetic transformation of the human skull[5] have been greatly strengthened by the discovery of giant hominids far exceeding in size any fossil or recent anthropoids; and they have been aided by tracing the lines of transformation up to recent man in at least one case, that of the *Gigantopithecus* → *Meganthropus* → *Pithecanthopus robustus* → *Pithecanthropus erectus* → *Homo*

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[1] Black, Teilhard de Chardin, Young, and Pei, 1933.

[2] Weidenreich, 1943b.
[3] Weidenreich, 1943a, and above.
[4] Weidenreich, 1943b.
[5] Weidenreich, 1941b.

soloensis→Wadjak man→Australian. When a type like a large gorilla, with a cranial capacity of about 600 cc., is assumed as the original ancestral form from which modern man, with an average cranial capacity of about 1300 cc., has developed, it is obvious that, during this transformation, the skull must have undergone great changes. The differences between the original and the modern forms of the skulls are surprisingly similar to the differences between the highly differentiated skulls of such dwarf dog types as the King Charles spaniel and the Pekinese, on the one hand, and the skull of such large and certainly more ancestral-like dog types as the Irish wolf hound, on the other. In the first case the cranial capacity is 55 cc.; in the latter it is 145 cc. However, in the wolf hound the ratio of brain weight to body weight is 1:355, while in the dwarf dogs it is only 1:31. In large gorilla this ratio is 1:350, while in man it is about 1:46. From these facts it can be deduced that small types have relatively larger brains than large ones. Therefore, the brain of the small types retains a proportionately much larger space than it does in the latter, and, consequently, the brain case proper tends to take possession of the whole skull with the result that all superstructures vanish. As the brain case increases, the masticatory apparatus correspondingly decreases; the jaws become shorter and retreat below and behind the line of the forehead instead of projecting beyond that line as in skulls with smaller brain cases.

The example of the dog has its analogy in the differences between the skulls of the lion and the wildcat. The ratio of brain weight to body weight is 1:550 in the lion, but only 1:100 in the wildcat. As do the dogs, so these wildcats demonstrate that it is the expansion of the brain which causes the transformation of the skull. Whether the usurpation of the larger space is the consequence of a relative or absolute increase in brain size is irrelevant; the effect on the form of the skull will be the same. The evolution of man is characterized by the gradual enlargement of the brain; its expansion and the consequent dominance of the brain case over the remaining parts of the skull, in this instance, seem to be an absolute and not a relative matter. Yet the unexpected appearance of giants in human ancestry necessitates a definite change in this point of view. The absolute increase of the brain during human evolution can be taken for granted, but the relative factor also seems to play an important role. When the same genetic type produces both giant and dwarf forms without any alteration in their evolutionary character, the dwarf form will have a relatively larger brain case than the giant form, the superstructures of the skull will disappear, and the jaws will become shorter and weaker. Therefore, the giant form equipped with superstructures, etc., appears to be more primitive when compared with the dwarf form, even if both belong to the same phylogenetic level.

B. SPECIAL MORPHOLOGICAL CONCLUSIONS WITH REGARD TO THE DEVELOPMENT OF THE HUMAN MANDIBLE

The character of the calvaria and maxilla of *Pithecanthropus robustus* as the most primitive hominid type so far known made it possible to arrive at some conclusions concerning the kind of transformation the hominid skull has undergone in reaching the modern human type. For a full discussion of the problem, the reader is referred to my paper on the *Sinanthropus* skull,[1] where *Pithecanthropus robustus* figures as *Pithecanthropus* Skull IV. The discovery of *Meganthropus* and *Gigantopithecus* provided no new basis for an extension of this discussion, because no cranial bones except the mandible of

Meganthropus were found. However, since the development of the human mandible has been a favorite topic of investigation, discussion, and controversy for many years, any new form contributes to elucidation and clarification.

In particular, the development of the chin always held the center of interest. In early hominids there is neither a "mentum ossum" nor a "trigonum mentale,"[2] both features characteristic of modern man. The chin develops relatively late, that is, certainly not before man passes from the Neanderthal stage into that of modern man. Its appearance marks one of the

[1] Weidenreich, 1943b.

[2] Weidenreich, 1934, 1936.

last steps in human evolution, and it coincides with the greatest reduction of the face, jaws, and teeth in size and robustness. This conception presumes that the mandible, especially the chin region, was more massive in the first human evolutionary stages and that the special relief has been carved out, as it were, by the reduction of other parts. When one compares the chin region of the *Meganthropus* mandible with that of modern man, there is scant doubt that such a reduction really took place. In three previous publications[1] I maintained this view against the claims of other students who considered the human chin to be the product of special muscles[2] or as a primary primitive feature of hominids.[3] The reader interested in the details of these controversies is referred to the papers cited. It is sufficient here to point out only the main issues. Walkhoff opined that the faculty of speech, acquired by man in contrast to the great apes, is responsible for the form of the chin through the particular effect of the tongue muscles (M. genioglossus, M. geniohyoideus, and M. digastricus). But he never took the pains to explain how those muscles which are inserted on the lingual side of the symphysis could produce an outgrowth like the mental trigonum on the opposite (buccal) side. H. Virchow and Van den Broek insisted that the mimical muscles attached to the facial surface model the chin; but they failed to demonstrate how these muscles, which in no case reach up to that region, produced a bulge like the trigonum. Bolk,[3] who built all his phylogenetic theories on a purely ontogenetic basis, without even consulting paleontological data or considering them, claimed that there were no fundamental differences between anthropoids and man. Both have, according to him, originally, "mesogeneiotic" mandibles, that is, the alveolar portion extended forward to the same frontal plane as the basal portion. Bolk argued that whereas in man the jaw has become a "eugeneiotic" one, the basal portion protruding in front of the alveolar portion, it has become an "ageneiotic" one in anthropoids, the alveolar portion protruding beyond the basal. The author was mistaken in assuming that both anthropoids and

[1] Weidenreich, 1904, 1934, 1936.
[2] Walkhoff, 1902; Van den Broek, 1919–1921; Virchow, 1920.
[3] Bolk, 1926b.

early hominids have a "mesogeneiotic" mandible and were, therefore, fundamentally alike in this respect. In reality they are alike in having "ageneiotic" mandibles, to use Bolk's terminology; that is to say, neither had a chin, as *Meganthropus* indubitably proves. This pri-
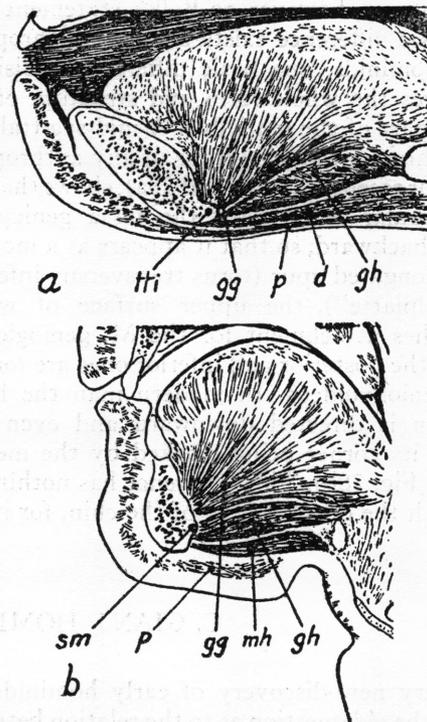
FIG. 28. Mid-sagittal section through the head of an adult male chimpanzee (a), and an adult male European (b).

mary, "ageneiotic" stage is retained in the anthropoids, while in man a general reduction of the facial skeleton sets in, which parallels the expansion of the brain case. The mandible becomes increasingly smaller and its original massiveness diminishes. As this process involves the teeth and especially their roots, the alveolar process shrinks progressively, while the base of the mandibular body resists. Consequently, the front of the jaw, between the teeth and the base, recedes first, originating Virchow's "incurvatio mandibulae anterior." The greater the reduction of the original massiveness of the bone, the more will its structure yield to static and dynamic forces acting either upon the entire bone or only upon certain parts of it. Such processes determine the characteristic shape of

the human mandible and mould its outer and inner surfaces, as I set forth in my earlier paper.[1] The development of the mental trigonum, the torus lateralis superior, the torus marginalis, the sulcus intertoralis, etc., of which no, or at best only faint, indications are discernible in *Meganthropus*, can be traced to these factors.

Contrary, however, to Bolk's statement that no basic difference exists between anthropoids and hominids, one basic difference decisively involves the whole form and structure of the front part of the mandible. A mid-sagittal section through the symphysis of any anthropoid, fossil or recent (Figs. 12 and 28a), shows that the mandibular base below the fossa genioglossi turns backward, so that it appears as a more or less elongated spur (torus transversus inferior, "Basalplatte"), the upper surface of which furnishes attachment for the M. genioglossus while the posterior and inferior ones are for the M. geniohyoideus. In modern man the basal portion is directed downward and even forward, its corner being marked by the mental spine (Fig. 28b). This difference has nothing to do with the development of the chin, for it oc-

curs long before there is any discernible suggestion of the chin structure. *Meganthropus* (Fig. 12a) shows it, although the exterior surface is rounded as in any anthropoid. This basic difference is also manifest in the position of the foramen mentale and foramen supraspinale. In anthropoids both are located at a much lower level than in hominids. This means that the basal portion of the mandible is higher and the alveolar portion lower in hominids than in anthropoids. The extension of the alveolar portion, however, is dependent on the size and strength of the teeth and especially of their roots. The fact that *Meganthropus* also reveals the typical human pattern in the location of these foramina indicates that the conditions present in hominids are the primary ones, while those in the anthropoids are secondary acquisitions. In infantile anthropoids the mental foramen is located at a relatively higher level than in adults because the deciduous teeth are smaller and, therefore, the alveolar process occupies a relatively smaller space in the mandible than in the permanent dentition.

C. GIANT HOMINIDS AND ANTHROPOIDS

Every new discovery of early hominids revives the old question as to the relation between hominids and anthropoids. When we review those anthropoid characters which were revealed by *Pithecanthropus robustus*, *Meganthropus*, and *Gigantopithecus* but which, so far, have not been noted in early hominids, we find the list a short one. They are: 1, the persistence of the upper diastema in *Pithecanthropus robustus*; 2, the fact that the second upper molar clearly exceeds the first and third in size in the same specimen; 3, the absence of rugosities on the palate of *Pithecanthropus robustus*; 4, the great length of the third molar in *Gigantopithecus* and the fact that it exhibits no sign of any reduction; 5, the dominance of the trigonid breadth over the talonid in the same specimen. It is interesting to note that the *Meganthropus* mandible, which must certainly be regarded as the most primitive hominid mandible so far discovered, has no specific anthropoid feature

except for the arrangement of the molar rows in more parallel lines.

Neither gigantism nor the tendency toward its development can be regarded as a specifically anthropoid character. Gorilla apparently has this tendency as does orang-utan, but chimpanzee does not. Nor does the massiveness of the cranial bones fall into this category, for none of the living anthropoids possesses this peculiarity.

On the other hand, certain specific hominid features are common to *Pithecanthropus robustus*, *Meganthropus*, and *Gigantopithecus*. Of these, the most prominent are the pattern of the cusps of the molar teeth, the shortness of the jaw, and the character of the canine group in the first two types. In addition to these characters, the *Meganthropus* mandible displays the typical hominid form of the lingual surface of the symphyseal region, a very pronounced incisura submentalis which is never found in anthropoids, and the typical hominid location of the mental foramen.

[1] Weidenreich, 1934.

To these anthropoid and hominid characteristics should be added those that are intermediate and represent an approach from the hominid line toward the general anthropoid stock. In *Meganthropus* the small angle of inclination of the front of the mandible, the *Dryopithecus* pattern of the lower molars, and the limited remnants of the cingulum belong, among others, to this group of characteristics. They testify to the common origin of the hominids and anthropoids which is already obvious, but they do not present any evidence as to where the diverging branches of this common stock met.

Meganthropus was certainly already in the human line, as was *Gigantopithecus*. Yet neither of these two new hominid types brings the human line closer to any of the three living anthropoids. Nor did analysis of the tooth pattern of *Gigantopithecus* and *Meganthropus* offer a definite clue as to which of the various fossil types of anthropoids—*Dryopithecus, Sivapithecus*, etc. —is the most closely related form. There is no closer approach to any one of these. *Dryopithecus giganteus* is gigantic when its third lower molar is compared with the same tooth of other *Dryopithecus* forms, but its size does not exceed that of a recent male gorilla, and its pattern is nearer to that of gorilla or chimpanzee than to that of the *Gigantopithecus* molar. The same is true of other smaller forms, such as *Dryopithecus darwini* which O. Abel[1] considered the most human-like primate tooth ever found. *Sivapithecus middlemissi* exhibits a "certain resemblance" to *Gigantopithecus* according to von Koenigswald[2] but the resemblance is no greater than that of the aforementioned forms. The mandible of *Meganthropus* differs from the mandibles of *Dryopithecus* and *Sivapithecus; Meganthropus* has hominid and the latter have anthropoid characters. All three forms agree in the thickness of the symphysis, but the formation of the entire buccal surface follows the anthropoid pattern in *Dryopithecus* and *Sivapithecus*. Only a single feature occurring in *Dryopithecus fontani* which A. Smith Woodward[3] described from the Lérida specimen is reminiscent of the condition in the *Meganthropus* mandible. This is the location of the digastric fossa which occupies the buccal side instead of the lower

margin of the mandible. However, the formation of a special median recessus, the lateral walls of which are occupied by the digastric fossae of either side, is a unique structure of *Meganthropus* which is not found in any other anthropoid or hominid, recent or fossil. It seems to represent a specific, primitive, hominid peculiarity which disappeared early in the course of human evolution. The same seems to be true, at least to a certain extent, of the incisura submentalis.

Though our search for anthropoid relatives of the newly discovered early hominids seems negative as far as the *Dryopithecus* group and related forms are concerned, it is more promising when the South African Australopithecinae are considered. In contrast to the other group, the Australopithecinae have the short muzzle and the homomorphic canine group in common with the hominids, and, therefore, also with *Meganthropus*. Moreover, there are two other features of the *Paranthropus* mandible which, so far, have been found only in hominids: 1, the mental foramen is located at a very high level and consists of three separated openings arranged in a semicircle; this location, together with the multiple openings and their arrangement, is characteristic of *Pithecanthropus* Mandible B, and *Sinanthropus* Mandibles A II, H I, and K I; 2, the mandible is very massive and thick; the average thickness amounts to 24.8 mm., which is only 2.2 mm. less than *Meganthropus* and is equaled only by gorilla. But in the latter the mandible, as a whole, is much larger and particularly higher, as shown by the index of robustness which, at foramen mentale level, is 77.4 in *Paranthropus*, while the average of gorilla is 49.4. Although the pattern of the lower molars of the Australopithecinae, especially that of *Australopithecus transvaalensis* Dart, comes very close to the hominid pattern, as we have said, that of *Paranthropus robustus* resembles gorilla or chimpanzee still more closely. This also holds true for the character of the symphysis. Broom[4] made a tentative reconstruction of a mid-sagittal section through the symphysis of *Paranthropus robustus* (Fig. 12i) and *Plesianthropus transvaalensis*. If these reconstructions prove to be correct, *Paranthropus* and *Plesianthropus* have no closer relation to *Meganthropus* than the *Dryopithecus* group, for

[1] Abel, 1902, 1931.
[2] Von Koenigswald, 1935.
[3] Smith Woodward, 1914.

[4] Broom, 1938.

the reconstructions of both show that the basal portion turns backward as is characteristic of anthropoids and not forward as is characteristic in hominids.

On these grounds then, it is clear that the South African fossil anthropoid group, as far as it is known, presents types with a closer approach to the hominids than any other group of fossil or recent anthropoids. But neither *Meganthropus* nor *Gigantopithecus* bridges the gap that separates the hominids from the Australopithecinae. The stock from which the hominids and Australopithecinae both branched off is not yet represented in our discoveries. But, unless all indications are deceptive, their common ancestor must have had a short face, small canines of the incisor type, bicuspid lower premolars (a homomorphic canine group), and a relatively small brain case. Whether the gigantic proportions of the early hominids are a special feature acquired by this group, or whether they made their appearance earlier, that is, before the Australopithecinae deviated, is beyond our knowledge for the present.

SUMMARY

1. Von Koenigswald's new discoveries of hominids from the Trinil beds of the Sangiran District of Java make indispensable a revision of their classification. If Dubois' Trinil skull cap (*Pithecanthropus* Skull I) is considered as the holotype of *Pithecanthropus erectus*, only the Sangiran skull cap of 1937 (Skull II) and the fragment of the juvenile skull of 1938 (Skull III) can be attributed to the same type. The Sangiran Skull IV, consisting of the posterior part of the brain case and the maxilla, exhibits such primitive and peculiar features (extraordinary massiveness, great size, heavy superstructures of special character, maxillary diastema, large palate without rugosities, predominance of the second upper molar) that it cannot be interpreted as merely a male individual of *Pithecanthropus erectus*, thereby, degrading, as it were, Skulls I–III to the rank of females. The trend to gigantism, obvious in Skull IV, and its more primitive character justify its separation from *Pithecanthropus erectus* and its classification as a new type for which I propose the name *Pithecanthropus robustus*.

2. The fragment of the Sangiran Mandible of 1941, named by von Koenigswald *Meganthropus palaeojavanicus*, is a true hominid, as the name indicates. It is of gigantic size and proportions and, in particular, extraordinary thickness. In spite of the enormous size, the jaw exhibits some characteristics typical of hominids; the canine group is homomorphic (small canine with a narrow root compressed in mesio-distal direction, and a bicuspidate first premolar); the dental arch forms a widely curved parabola with divergent side rows and no sharp angles in the line of the canines; there is only a moderate degree of prognathism; the lingual surface of the symphysis shows a shallow fossa genioglossi, the first trace of a mental spine, and a shortened and flattened "Basalplatte"; the mental foramen is located on a very high horizontal level. On the other hand, the mandible displays some undoubtedly simian peculiarities; the chin (mentum osseum and tuberculum symphyseos) is missing; the digastric fossa is situated on either lingual side of the symphysis region and resembles conditions found so far only in *Dryopithecus fontani* (Lérida); two relatively large nutritory canals penetrate forward into the bone, from the back of the fossa genioglossi; the premolars and molars are arranged in straight side rows. A special feature is the development of a median digastric recessus, the side walls of which lodge the digastric fossa on either side, and a very pronounced incisura submentalis; the first formation is recorded so far neither in hominids nor in anthropoids, the latter is slightly indicated in *Sinanthropus*, more so in the Heidelberg jaw, but absent in modern man as well as in anthropoids.

3. The fragment of the Sangiran Mandible of 1939, which von Koenigswald attributes to a female *Meganthropus palaeojavanicus*, cannot be identified because of its incompleteness (in particular of the premolar and canine region) and the uncertainty of any judgment based only on a cast. The bone and the teeth are larger than those of the *Pithecanthropus* Mandible B, but considerably smaller than those of *Meganthropus*, and in any case much smaller than may reasonably be expected from a female individual of the same type. As far as a verdict can be given, the jaw combines certain hominid and simian peculiarities; there was only a slight degree of prognathism, and the dental arch exhibits only a moderate angle in the line of the canine; the mental foramen is situated on a high, horizontal level. On the other hand, the condition of the symphysis is obscure and more like that of an anthropoid than a hominid. Whether the canine group had a homomorphic (hominid) or a heteromorphic (simian) character cannot be decided without a study of the original and the help of skiagrams.

4. The three molars of *Gigantopithecus* belong to at least two, possibly even to three, different individuals. Although all three teeth were acquired by von Koenigswald from a Chinese chemist's shop in Hong Kong, their condition (roots broken off and the exposed pulp cavities showing traces of a yellow matrix) and the character of other bone fragments and teeth associated with these molars (*Stegodon*, tapir, orang-utan) indicate that the *Gigantopithecus* material originates from the "yellow deposits" of caves in South China (probably in Kwangsi), and that *Gigantopithecus* belongs with the "Sino-Malayan fauna."

It can be proved that the *Gigantopithecus*

teeth are not the teeth of an anthropoid, as assumed by von Koenigswald, but the teeth of a true hominid, although of gigantic proportions. The patterns of the two third lower molars and that of the upper one are identical with the corresponding pattern of any hominid tooth, including modern man, not only with regard to their general character, but also to minute details; and they are to the same degree quite different from any known recent or fossil anthropoid. *"Gigantopithecus"* is not a "pithecus," but a giant "anthropus." His molars exceed in size by far any known hominid molars, and even those of the biggest gorilla. Apart from the size, the molars show a strange combination of primitive and advanced characters. The most striking primitive feature is the extraordinary size and, in particular, the length of the third lower molar and the pronounced preponderance of the trigonid breadth over the talonid breadth. In all other hominids, except the *Pithecanthropus* Mandible B, the third lower molar is reduced, especially in length, and chiefly at the expense of the talonid.

5. The hominids of the Sino-Malayan fauna, as far as they are known at present, represent a fairly continuous line proceeding from small types to gigantic ones in the following sequence: *Pithecanthropus erectus* (Skulls I, II, III), *Pithecanthropus robustus* (Skull IV), *Meganthropus palaeojavanicus*, *Gigantopithecus blacki*. As to their morphological characters, each larger type seems to be more primitive than the next smaller one. In other words, gigantism is a primitive character which has the tendency to diminish as evolution advances. This tendency is also strongly indicated by the massiveness of the cranial and limb bones (femur, humerus) of early hominids which cannot be directly qualified as giants. This massiveness decreases progressively and gives way occasionally even to a relatively pronounced fragility in modern man,

while it persists to a certain extent in other cases.

6. So far, there is no evidence that the morphological sequences of the hominid types of the Sino-Malayan fauna correlate with a chronological and stratigraphical sequence. The types recovered from Java are found in Trinil bed formations and are, therefore, ascribed to the Middle Pleistocene; the "yellow deposits" of the caves in South China, the source of *Gigantopithecus*, may also belong to the Middle Pleistocene, but possibly to the Lower Pleistocene. However, there is strong reason, based on the geological conditions of the Pleistocene in Java, to assume that the embedding of the material in Trinil strata is of an accidental nature. As the deposit is undoubtedly secondary, the types may have lived in an earlier or even later geological period than is suggested by the localities from which they were collected.

7. It is definite that *Sinanthropus pekinensis* represents about the same evolutionary stage as *Pithecanthropus erectus*. His relation to *Pithecanthropus robustus*, *Meganthropus*, and *Gigantopithecus* is, therefore, similar to that of *Pithecanthropus erectus*. *Gigantopithecus* as a South Chinese ancestral form of *Pithecanthropus* may also be an ancestral form of *Sinanthropus*. When the *Pithecanthropus* line extended southward from South China to Java, another branch may have extended northward to North China and given origin to *Sinanthropus*, but in this case no intermediate forms so far have been discovered.

8. The new finds do not offer a new clue as to the special anthropoid form from which the hominids were derived. One of the characteristic primitive structures of *Meganthropus* recalls the condition of *Dryopithecus fontani* (Lérida), but the pattern neither of his teeth nor of the *Gigantopithecus* molars reveals any closer approach to the *Dryopithecus* and related types or to the Australopithecinae of South Africa.

LITERATURE CITED

ABEL, O.
1902. Zwei neue Menschenaffen aus den Leitha-
kalkbildungen des Wiener Beckens. Sitz-
ber. Akad. Wiss. Wien, Math.-Nat. Kl.,
vol. 111, div. 1, pp. 1171–1206.
1931. Die Stellung des Menschen im Rahmen der
Wirbeltiere. Jena, Gustav Fischer.

ADLOFF, P.
1908. Das Gebiss des Menschen und der Anthro-
pomorphen. Berlin, Julius Springer.
1916. Die Entwicklung des Zahnsystems der
Saügetiere und des Menschen. Berlin,
Hermann Meusser.
1937. Über die primitiven und die sogenannten
"pithecoiden" Merkmale im Gebiss des
rezenten und fossilen Menschen und ihre
Bedeutung. Zeitschr. für Anat. und Ent-
wick.-gesch., vol. 107, pp. 68–82.

ASHLEY-MONTAGU, M. F.
1943. Variation of the diastemata in the denti-
tion of the anthropoid apes and its signifi-
cance for the origin of man. Amer. Jour.
Phys. Anthrop., new ser., vol. 1 (old ser.,
vol. 30), no. 4, pp. 325–353.

BIEN, M. N.
1940. Preliminary observation on the Cenozoic
geology of Yunnan. Bull. Geol. Soc. China,
vol. 20, no. 2, pp. 179–204.

BIEN, M. N., AND L. P. CHIA
1938. Cave and rock-shelter deposits in Yunnan.
Bull. Geol. Soc. China, vol. 18, pp. 325–
347.

BLACK, DAVIDSON, P. TEILHARD DE CHARDIN, C. C.
YOUNG, AND W. C. PEI
1933. Fossil man in China. Geol. Mem. (Mem.
Geol. Surv. China), ser. A, no. 11, pp.
1–166.

BOLK, LOUIS
1914. Odontologische Studien II. Die Morpho-
genie der Primatenzähne. Jena, Gustav
Fischer.
1926a. Das Problem der Menschwerdung. Jena,
Gustav Fischer.
1926b. Die Entstehung des Menschenkinnes. Ein
Beitrag zur Entwicklungsgeschichte des
Unterkiefers. Verhandel. K. Akad. We-
tensch. Amsterdam, Afd. Naturk. (2
Sect.), vol. 13, no. 5.

BOULE, MARCELLIN
1911–1913. L'homme fossile de la Chapelle-aux-
Saints. Ann. Paléont., vols. 6, 7, 8, pp.
3–278.

BRANCO, W.
1898. Die menschenähnlichen Zähne aus dem
Bohnerz der schwäbischen Alb. Jahresh.

Ver. für vaterl. Naturk. Württemberg,
pt. 1, pp. 1–144.

BROOM, R.
1937. Discovery of a lower molar of *Australo-
pithecus*. Nature, vol. 140, no. 3546, pp.
681–682.
1938. Further evidence on the structure of the
South African Pleistocene anthropoids.
Ibid., vol. 142, no. 3603, pp. 897–899.
1939a. Les singes anthropoides fossiles de l'Afri-
que du Sud et leur relations à l'homme.
Rev. Sci., no. 3, pp. 172–175.
1939b. The dentition of the Transvaal Pleistocene
anthropoids, *Plesianthropus* and *Paran-
thropus*. Ann. Transvaal Mus., vol. 19,
pt. 3, pp. 303–314.

BÜNTE, H., AND H. MORAL
1910. Über das Foramen mentale. Korresp.
Deutschen Zahnärzte, vol. 39, pp. 140–
153.

BURKITT, A. N.
See Gullberg, J. E., and A. N. Burkitt.

CHANG, HSI-CHIH
1934. On some fossil mammals from Kwangsi,
South China. Geol. Surv. Kwantung and
Kwangsi, special publ. no. 15, pp. 1–14.
See Teilhard de Chardin, P., C. C. Young,
W. C. Pei, and H. C. Chang.

CHIA, L. P.
See Bien, M. N., and L. P. Chia.

COLBERT, EDWIN H.
1943. Pleistocene vertebrates collected in Burma
by the American Southeast Asiatic Ex-
pedition. Trans. Amer. Phil. Soc., Phila-
delphia, new ser., vol. 32, pt. 3, pp. 395–
429.

CUNNINGHAM, D. J.
1890. The skeleton of the Irish giant, Cornelius
Magrath. Trans. Roy. Irish Acad., vol. 29,
pt. 16, pp. 553–612.

DART, RAYMOND A.
1934. The dentition of "*Australopithecus afri-
canus.*" Folia Anat. Japonica, vol. 12, pp.
207–221.

DAWSON, CH., AND A. SMITH WOODWARD
1913. On the discovery of a palaeolithic human
skull and mandible in a flint-bearing gravel
overlying the Wealden (Hastings Beds)
at Piltdown, Fletching (Sussex). Quart.
Jour. Geol. Soc. London, vol. 69, pp. 117–
151.
1914. Supplementary note on the discovery of a
palaeolithic human skull and mandible at
Piltdown (Sussex). *Ibid.*, vol. 70, pp.
82–99.

DUBOIS, EUGEN
1922. The Proto-Australian fossil man of Wad-jak, Java. Proc. Roy. Acad. Wetensch. Amsterdam, Sect. Sci., vol. 23, pp. 1013–1051.
1924. On the principal characters of the cranium and the brain, the mandible and the teeth of *Pithecanthropus erectus*. *Ibid.*, Sect. Sci., vol. 27, pp. 265–278, 459–464.
1937. On the fossil human skulls recently discovered in Java, and *Pithecanthropus erectus*. Man, vol. 37, Jan., no. 1, pp. 1–7.

FAWCETT, EDWARD
1904. Patrick Cotter—the Bristol giant. Jour. Roy. Anthrop. Inst., vol. 39, pp. 196–208.

FREUDENBERG, W.
1928. Die ersten Primatenfunde von Bammenthal bei Mauer a. d. Elsenz aus praeglacialen Neckarkiesen. Verhandl. Gesellsch. Phys. Anthrop., Sonderh. 3 zum Jahrg. 5, Anthrop. Anz., pp. 68–82.
1929. Vorlage von Schädelfragmenten und Scapularest des *Hemianthropus osborni* gen. et spec. nov. nebst andern Primatenresten aus Bammenthal a.d. Elsenz. Anat. Anz. Ergänzungsh. zum vol. 67 (1929) Verhandl. Anat. Gesellsch. 38, Versammlung in Tübingen, pp. 240–245.
1931. Der gegenwärtige Stand meiner Untersuchungen an den Primatenresten aus den "Elsenzschichten" (nom. nov.) um Heidelberg, insbesondere über Skeletteile gigantischer Primaten. Zeitschr. Deutsche Geol. Gesellsch., vol. 83, no. 9, pp. 642–645.
1938. Beiträge zur Natur- und Urgeschichte Westdeutschlands. Heidelberg, C. Winter, no. 2, pp. 3–56.

FROMAGET, JACQUES, AND EDMOND SAURIN
1936. Note préliminaire sur les formations cénozoiques et plus récentes de la chaine annamitique septentrionale et du Haut-Laos (Stratigraphie, préhistoire, anthropologie). Bull. Serv. Géol. Indo-Chine, vol. 22, fasc. 3, pp. 5–48.

GEDDES, A. C.
1911. Report upon an acromegalic skeleton. Jour. Anat. Physiol., vol. 45, pp. 256–292.

GIESELER, W.
1926. Zur Beurteilung des Eppelsheimer Femur. Verhandl. Gesellsch. Phys. Anthrop., vol. 1, Sonderh. 1 zum Jahrg. 3, Anthrop. Anz., pp. 34–35.

GORJANOVIĆ-KRAMBERGER, K.
1906. Der diluviale Mensch von Krapina in Kroatien. *In* Studien über die Entwicklungsmechanik des Primatenskelettes, etc. Wiesbaden, no. 2, pp. 59–277.

1909. Der vordere Unterkieferabschnitt des altdiluvialen Menschen in seinem genetischen Verhältnis zum Unterkiefer des rezenten Menschen und dem der Anthropoiden. Zeitschr. für Indukt. Abstammungs- und Vererbungslehre, vol. 1, pp. 411–439.

GRANGER, W.
See Matthew, W. D., and W. Granger.

GREGORY, WILLIAM K.
1916. Studies on the evolution of the primates. Bull. Amer. Mus. Nat. Hist., vol. 35, pp. 239–355.
1925. The biogenetic law and the skull form of primitive man. Amer. Jour. Phys. Anthrop., vol. 8, no. 4, pp. 373–378.

GREGORY, WILLIAM K., AND MILO HELLMAN
1926. The dentition of *Dryopithecus* and the origin of man. Anthrop. Papers, Amer. Mus. Nat. Hist., vol. 28, pt. 1, pp. 1–123.
1938. Evidence of the australopithecine man-apes on the origin of man. Science, vol. 88, no. 2296, pp. 615–616.
1939a. The dentition of the extinct South African man-ape *Australopithecus (Plesianthropus) transvaalensis* Broom. A comparative and phylogenetic study. Ann. Transvaal Mus., vol. 19, pt. 4, pp. 339–373.
1939b. The South African fossil man-apes and the origin of the human dentition. Jour. Amer. Dent. Assoc., vol. 26, pp. 558–564.

GREGORY, WILLIAM K., MILO HELLMAN, AND G. EDWARD LEWIS
1938. Fossil anthropoids of the Yale-Cambridge India Expedition of 1935. Carnegie Inst. Washington Publ., no. 495, pp. 1–27.

GULLBERG, J. E., AND A. N. BURKITT
1925. An abnormal skull from New Guinea, with remarks on the structure of the mandible. Jour. Anat., London, vol. 59, pp. 41–55.

HELLMAN, MILO
1928. Racial characters in human dentition. Proc. Amer. Phil. Soc., Philadelphia, vol. 67, pp. 157–174.
See Gregory, William K., and Milo Hellman.
See Gregory, William K., Milo Hellman, and G. Edward Lewis.

HILL-TOUT, CHARLES
1921. The phylogeny of man from a new angle. Trans. Roy. Soc. Canada, vol. 15, sect. 2, pp. 47–82.

HRDLIČKA, A.
1924. New data on the teeth of early man. Amer. Jour. Phys. Anthrop., vol. 7, no. 1, pp. 109–132.

KEITH, ARTHUR
1913. Problems relating to the teeth of the earlier forms of prehistoric man. Proc.

Roy. Soc. Med., vol. 6, pt. 3, Odont. Sect., pp. 103–124.

1925. The antiquity of man. London, vol. 2.
See McCown, Theodore, and Arthur Keith.

KLAATSCH, H.
1920. Der Werdegang der Menschheit und die Entstehung der Kultur. Berlin.

VON KOENIGSWALD, G. H. R.
1935. Eine fossile Saügetierfauna mit Simia aus Südchina. Proc. K. Akad. Wetensch. Amsterdam, vol. 38, pt. 2, pp. 872–879.
1936. Ein fossiler Hominide aus dem Altpleistocän Ostjavas. De Ingenieur in Nederlandsch-Indië, no. 8, pp. 149–157.
1937. Ein Unterkieferfragment des *Pithecanthropus* aus den Trinilschichten Mitteljavas. Proc. K. Akad. Wetensch. Amsterdam, vol. 40, pp. 883–893.
1938. Ein neuer Pithecanthropusschädel. *Ibid.*, vol. 41, pp. 185–192.
1938–1939. The relationship between the fossil mammalian faunae of Java and China, with special reference to early man. Peking Nat. Hist. Bull., vol. 13, pp. 293–298.
1939. Das Pleistocän Javas. Quartär, vol. 2, pp. 28–53.
1942. The South African man-apes and *Pithecanthropus*. Carnegie Inst. Washington Publ., no. 530, pp. 205–222.

VON KOENIGSWALD, G. H. R., AND FRANZ WEIDENREICH
1938. Discovery of an additional *Pithecanthropus* skull. Nature, vol. 142, no. 3598, p. 715.
1939. The relationship between *Pithecanthropus* and *Sinanthropus*. *Ibid.*, vol. 144, no. 3657, pp. 926–929.

KOLLMANN, J.
1905. Neue Gedanken über das alte Problem von der Abstammung des Menschen. Korresp.-Bl. Deutsche Gesellsch. Anthrop. Ethnöl. u. Urgesch., vol. 36, nos. 2 and 3, pp. 9–20.

LEAKEY, L. S. B.
1943. A Miocene anthropoid mandible from Rusinga, Kenya. Nature, vol. 152, no. 3855, pp. 319–320.

VON LENHOSSEK, M.
1920. Das innere Relief des Unterkieferastes. Arch. für Anthrop., new ser., vol. 18 (old ser., vol. 46), pp. 49–59.

LEWIS, G. EDWARD
See Gregory, William K., Milo Hellman, and G. Edward Lewis.

LORENZ VON LIBURNAU, L. R.
1905. *Megaladapis edwardsi* G. Grandidier. Denkschr. Akad. Wiss. Wien, Math.-Nat. Kl., vol. 77, pp. 451–490.

McCOWN, THEODORE, AND ARTHUR KEITH
1939. The stone age of Mount Carmel. The fossil human remains from the Levalloiso-Mousterian. Oxford, vol. 2, pp. 1–390.

McGREGOR, J. H.
1916. Restoration of the Piltdown skull. *In* Osborn, H. F., Men of the Old Stone age. New York, pp. 131, 140, 142, 143, 145.

MARTIN, R.
1928. Lehrbuch der Anthropologie in systematischer Darstellung mit besonderer Berücksichtigung der Anthropologischen Methoden. Jena, 3 vols.

MATTHEW, W. D.
1926. The evolution of the horse. A record and its interpretation. Quart. Rev. Biol., vol. 1, pp. 139–185.

MATTHEW, W. D., AND W. GRANGER
1923. New fossil mammals from the Pliocene of Sze-chuan, China. Bull. Amer. Mus. Nat. Hist., vol. 48, pp. 563–598.

MILLER, G. S., JR.
1923. Notes on the casts of the *Pithecanthropus* molars. Bull. Amer. Mus. Nat. Hist., vol. 48, pp. 527–530.

MORAL, H.
See Bünte, H., and H. Moral.

MUMMERY, HOWARD J.
1924. The microscopic and general anatomy of the teeth, human and comparative. 2d ed. Oxford.

OPPENOORTH, W. F. F.
1932a. *Homo (Javanthropus) soloensis*, een plistoceene mensch van Java. Wetensch. Meded. no. 20, Dienst Mijnbouw Nederlandsch-Indië, pp. 49–74.
1932b. Ein neuer diluvialer Urmensch von Java. Natur und Museum, vol. 62, pp. 269–279.

PEI, W. C.
1935a. On a mesolithic (?) industry of the caves of Kwangsi. Bull. Geol. Soc. China, vol. 14, pp. 393–412.
1935b. Fossil mammals from the Kwangsi caves. *Ibid.*, vol. 14, pp. 413–425.
See Black, Davidson, P. Teilhard de Chardin, C. C. Young, and W. C. Pei.
See Teilhard de Chardin, P., C. C. Young, W. C. Pei, and H. C. Chang.

PILGRIM, GUY E.
1915–1916. New Siwalik primates and their bearing on the question of the evolution of man and the Anthropoidea. Rec. Geol. Surv. India, vol. 45, pt. 1, pp. 1–74.
1927. A *Sivapithecus* palate and other primate fossils from India. Palaeont. Indica, new ser., vol. 14, pp. 1–26.

RANKE, J.
1897.   Uber die individuellen Variationen im Schädelbau des Menschen. Anthrop. Korrespondensbl., 1897, pp. 139–146.

REMANE, A.
1921.   Beiträge zur Morphologie des Anthropoidengebisses. Arch. für Naturgesch., vol. 87, div. A, no. 11, pp. 1–179.

SAURIN, EDMOND
See Fromaget, Jacques, and Edmond Saurin.

SCHMIDT, EMIL
1905.   Prähistorische Pygmäen. Globus, vol. 87, pp. 309–312, 325–329.

SCHMIDT, P. W.
1910.   Die Stellung des Pygmäenvölker in der Entwicklungsgeschichte des Menschen. *In* Buschan, G., Studien und Forschungen zur Menschen- und Völkerkunde. Stuttgart, vol. 6–7, pp 1–315.

SCHOETENSACK, O.
1908.   Der Unterkiefer des *Homo Heidelbergensis*. Leipzig.

SCHULTZ, ADOLPH H.
1933.   Die Körperproportionen der erwachsenen catarrhinen Primaten, mit spezieller Berücksichtigung der Menschenaffen. Anthrop. Anz., vol. 10, pp. 154–185.
1937.   Proportions, variability and asymmetries of the long bones of the limbs and the clavicles in man and apes. Human Biol., vol. 9, pp. 281–328.

SCHULZ, H. E.
1933.   Ein Beitrag zur Rassenmorphologie des Unterkiefers. Zeitschr. für Morph. und Anthrop., vol. 32, pp. 275–366.

SCHWALBE, G.
1906.   Zur Frage der Abstammung des Menschen. Zeitschr. für Morph. und Anthrop., suppl. 1, pp. 9–80.
1916.   Über den fossilen Affen *Oreopithecus Bambolii*. Zugleich ein Beitrag zur Morphologie der Zähne der Primaten. *Ibid.*, vol. 19, pp. 149–254.

SEER, M.
1925.   Zur Frage der Formveränderung des Unterkiefers bei Akromegalie. D. Monatsschr. Zahnheilk., vol. 43, pp. 582–595.

SELENKA, E.
1898.   Rassen, Schädel und Bezahnung des Orangutan. *In* Menschenaffen (Anthropomorphae). Wiesbaden, pt. 1, pp. 1–91.

SIMONTON, F. V.
1923.   Mental foramen in the anthropoids and in man. Amer. Jour. Phys. Anthrop., vol. 6, no. 4, pp. 413–421.

SMITH WOODWARD, ARTHUR
1914.   On the lower jaw of an anthropoid ape (*Dryopithecus*) from the Upper Miocene of Lérida (Spain). Quart. Jour. Geol. Soc. London, vol. 70, pp. 316–320.
1917.   Further note on the Piltdown gravel with evidence of a second skull of *Eoanthropus dawsoni*. *Ibid.*, vol. 73, pp. 1–10.
See Dawson, Ch., and A. Smith Woodward.

TEILHARD DE CHARDIN, P., C. C. YOUNG, W. C. PEI, AND H. C. YOUNG
1935.   On the cenozoic formations of Kwangsi and Kwantung. Bull. Geol. Soc. China, vol. 14, pp. 179–210.
See Black, Davidson, P. Teilhard de Chardin, C. C. Young, and W. C. Pei.

DE TERRA, HELLMUT
1943a.   Research on early man in Burma. Trans. Amer. Phil. Soc., Philadelphia, new ser., vol. 32, pt. 3, pp. 265–339.
1943b.   Pleistocene geology and early man in Java. *Ibid.*, new ser., vol. 32, pt. 3, pp. 437–464.

DE TERRA, MAXIMILIAN
1905.   Beiträge zu einer Odontographie der Menschenrassen. Berlin.

THOMSON, H. A.
1890.   Acromegaly, with the description of a skeleton. Jour. Anat. Physiol., vol. 24, pp. 475–492.

TOLDT, C.
1907.   Der M. digastricus und die Muskeln des Mundhöhlenbodens beim Orang. Sitzber. Akad. Wiss. Wien, Math.-Nat. Kl., vol. 116, div. 3, pp. 443–456.

TOPINARD, P.
1886.   Les caractères simian de la machoire de La Naulette. Rev. d'Anthrop., ser. 3, vol. 1, pp. 385–431.
1892.   De l'évolution des molaires et prémolaires chez les primates et en particulier chez l'homme. L'Anthropologie, vol. 3, pp. 641–710.

VAN DEN BROEK, H. I. P.
1919–1921.   Über Muskelinsertionen und Ursprünge am Unterkiefer; ein Beitrag zur Kinnfrage. Zeitschr. für Morph. und Anthrop., vol. 21, pp. 227–284.

VAN ES, L. J. C.
1931.   The age of *Pithecanthropus*. The Hague.

VIRCHOW, HANS
1916.   Zahnbogen und Alveolarbogen. Zeitschr. für Ethnol., vol. 48, pp. 277–295.
1920.   Die menschlichen Skeletreste aus dem Kämpfe'schen Bruch im Travertin von Ehringsdorf bei Weimar. Jena.

VRAM, UGO G.
1898.   Studio sui denti molari umani. Atti Soc. Romana, Antrop., vol. 5, pp. 155–196.

WALKHOFF, O.
1902. Der Unterkiefer der Anthropomorphen und des Menschen in seiner functionellen Entwicklung und Gestalt. *In* Selenka, E., Menschenaffen (Anthropomorphae). Wiesbaden, pt. 4, pp. 209–327.

WEIDENREICH, FRANZ
1904. Die Bildung des Kinnes und seine angebliche Beziehung zur Sprache. Anat. Anz., vol. 24, pp. 545–555.
1925. Domestikation und Kultur in ihrer Wirkung auf Schädelform und Körpergestalt. Zeitschr. für Konstitutionslehre, vol. 11, pp. 1–52.
1934. Das Menschenkinn und seine Entstehung. Eine Studie und Kritik. Ergeb. Anat. Entwickelungsgesch., vol. 31, pp. 1–124.
1936. The mandibles of *Sinanthropus pekinensis*: a comparative study. Palaeont. Sinica, ser. D, vol. 7, fasc. 3, pp. 1–162.
1937a. The dentition of *Sinanthropus pekinensis*: a comparative odontography of the hominids. *Ibid.*, new ser. D, no. 1, whole ser. no. 101, pp. 1–180.
1937b. The relation of *Sinanthropus pekinensis* to *Pithecanthropus*, *Javanthropus* and Rhodesian man. Jour. Roy. Anthrop. Inst., vol. 67, pp. 51–65.
1938. *Pithecanthropus* and *Sinanthropus*. Nature, vol. 141, no. 3565, pp. 376–379.
1940a. Man or ape? Nat. Hist., vol. 45, no. 1, pp. 32–37.
1940b. The torus occipitalis and related structures and their transformations in the course of human evolution. Bull. Geol. Soc. China, vol. 19, pp. 480–558.
1941a. The extremity bones of *Sinanthropus pekinensis*. Palaeont. Sinica, new ser. D, no. 5, whole ser. no. 116, pp. 1–150.
1941b. The brain and its role in the phylogenetic transformation of the human skull. Trans. Amer. Phil. Soc., Philadelphia, new ser., vol. 31, pt. 5, pp. 321–442.
1943a. The "Neanderthal Man" and the ancestors of "*Homo Sapiens*." Amer. Anthrop., new ser., vol. 45, no. 1, pp. 39–48.
1943b. The skull of *Sinanthropus pekinensis*: a comparative study on a primitive hominid skull. Palaeont. Sinica, new ser. D, no. 10, whole ser. no. 127, pp. 1–484.
1944. Giant early man from Java and South China. Science, vol. 99, pp. 479–482.
1945. The puzzle of *Pithecanthropus*. Science and Scientists in the Netherland Indies, vol. 1, pp. 380–390.
See von Koenigswald, G. H. R., and Franz Weidenreich.

WEINERT, HANS
1928. *Pithecanthropus erectus*. Zeitschr. für Anat. und Entwicklungs-Gesch., vol. 87, pp. 429–547.

WELCKER, H.
1902. Die Zugehörigkeit eines Unterkiefers zu einem bestimmten Schädel, nebst Untersuchungen über sehr auffällige, durch Auftrocknung und Wiederanfeuchtung bedingte Grössen- und Formveränderungen des Knochens. Arch. für Anthrop., vol. 27, pp. 37–106.

YOUNG, C. C.
1932a. On some fossil mammals from Yunnan. Bull. Geol. Soc. China, vol. 11, no. 4, pp. 383–393.
1932b. On the Artiodactyla from the *Sinanthropus* site at Choukoutien. Palaeont. Sinica, ser. C, vol. 8, fasc. 2, pp. 1–158.
See Black, Davidson, P. Teilhard de Chardin, C. C. Young, and W. C. Pei.
See Teilhard de Chardin, P., W. C. Pei, and H. C. Chang.

ZDANSKY, OTTO
1925. Fossile Hirsche Chinas. Palaeont. Sinica, ser. C, vol. 2, fasc. 3, pp. 1–90.
1928. Die Säugetiere der Quartärfauna von Chou-Kou-Tien. *Ibid.*, ser. C, vol. 5, fasc. 4, pp. 3–146.

ZUCKERKANDL, E.
1902. Makroskopische Anatomie der Mundhöhle. *In* Scheff, Julius, Handbuch der Zahnheilkunde. Dritte Auflage. Vienna, vol. 1.

EXPLANATION OF ILLUSTRATIONS

9. Sangiran Mandible of 1939, and Kedung Brubus Mandible

  a. Sangiran Mandible of 1939. Drawings from the cast. ×1
    1. Buccal view
    2. Lingual view
    3. Occlusal view
    4. Viewed from behind

  b. Sangiran Mandible of 1939, partly reconstructed. ×⅔
    1. Buccal view
    2. Frontal view
    3. Occlusal view
    4. Basal view
    5. Mid-sagittal section through the symphysis and lingual side

  c. Mandible of Kedung Brubus (*Pithecanthropus erectus*). ×1
    1. Buccal view
    2. Basal view

  Abbr.: al_1, alveolus of the posterior root of P_1; al_2, alveolus of the anterior root of P_1 (?); al_3, alveolus of the anterior root of P_2 (?); cr., crista masseterica (?); d., depressio masseterica (?); fd., fossa digastrica; fm., foramen mentale; fsa., fossa subalveolaris anterior; fsp., fossa subalveolaris posterior; ja., jugum alveolare P_1; lm., linea mylohyoidea (?); pa., processus alveolaris; r., root of canine (?); s1, septum alveolare between C and I_2 (?); s2, septum alveolare between P_1 and C (?); si., sulcus intertoralis; tls., torus lateralis superior; tm., torus marginalis; tti., torus transversus inferior; tts., torus transversus superior

10. Teeth of *Gigantopithecus blacki* von Koenigswald compared with those of other hominids and anthropoids

  a1. *Gigantopithecus blacki* von Koenigswald, left M_3. Photograph from the cast. Occlusal view. ×2

  a2. Gorilla, male (C.R.L.P. No. 329), left M_3. Occlusal view. ×2

  a3. Orang-utan, male, fossil, cave of Kwangsi (C.R.L.P.), left M_3. Drawing from the original. Occlusal view. ×2

  a4. Chimpanzee, male (A.M.N.H. No. 310648), left M_3. Occlusal view. ×2

  b1. *Gigantopithecus blacki*, left M_3. Drawing from the cast. Occlusal view. ×2

  b2, b3, b4. *Sinanthropus pekinensis.* Occlusal views. ×2
    b2. No. 137[1] (see Weidenreich, 1937a, Fig. 339), left M_1. Drawing from the cast
    b3. No. 36 (see Weidenreich, 1937a, Fig. 139), left M_1. Photograph from the cast
    b4. No. 44 (see Weidenreich, 1937a, Fig.

290), left M_2. Photograph from the original

  b5, b6. Recent man; American Indian, Tarasco, Mexico (A.M.N.H. No. 99-7553), left M_3. Occlusal view. ×2
    b5. Drawing from the original
    b6. Photograph from the original

  c. *Gigantopithecus blacki.* Photograph from the original. Occlusal view. Copy of von Koenigswald's Fig. 14b (1935). ×2

  d1, d2. Recent man. Copies of Adloff's illustrations. ×2
    d1. Left M_3 (1908, Pl. 5, Fig. 22)
    d2. Left molar (1916, Fig. 70)

  e1. *Gigantopithecus blacki*, left M_3. ×1

  e2. Male gorilla (A.M.N.H. No. 54089), left M_3. ×1

  e3. *Sinanthropus pekinensis*, No. 36, left M_1. ×1

  e4. Recent man (American Indian, see b5), left M_3. ×1

  f. *Gigantopithecus blacki*, right M_3. The same tooth as depicted in Fig. c. ×1

  g. *Dryopithecus giganteus pilgrimi*, right M_3. Photograph from the cast. ×1

  h. Buccal views of the same four teeth as depicted in Fig. e. ×1

  h1. *Gigantopithecus*
  h2. Gorilla
  h3. *Sinanthropus*, No. 36
  h4. Recent man (American Indian)

  Abbr.: d., distal side; dw., deflecting wrinkle of the metaconid; ed., entoconid; fa., fossa anterior; hd., hypoconid; m., mesial side; md., metaconid; msd., mesoconid; pd., protoconid; tam., tuberculum accessorium internum; t6, "tuberculum six"

11. Teeth of *Gigantopithecus blacki* von Koenigswald compared with those of other hominids and anthropoids

  a. *Gigantopithecus blacki*, left M_3. Drawings from the cast. ×2
    1. Buccal view
    2. Lingual view
    3. Mesial view
    4. Distal view

  b. *Gigantopithecus blacki*, left M_3. Drawing from the cast. ×2. Viewed from below

  c. Buccal views of:
    1. Gorilla (see Pl. 10, e2). ×2
    2. Orang-utan, male (A.M.N.H. No. 124), left M_3. ×2
    3. Chimpanzee, male (A.M.N.H. No. 35550), left M_3. ×2
    4. Recent man, American Indian (see Pl. 10, b5, b6). ×2

  d. *Sinanthropus pekinensis*, No. 137[1], left M_1 (see Pl. 10, b2). Drawing from the original. Buccal view. ×2

e. *Australopithecus africanus* Dart, right M₁ (see Weidenreich, 1937a, Fig. 156). Occlusal view. ×2

f1. Gibraltar child, right M₂ (see Weidenreich, 1937a, Fig. 168). Occlusal view. ×2

f2. Krapina, left M₁ (after Gorjanović-Kramberger, 1906, Pl. 13, Fig. 5). Occlusal view. ×2

g1. *Dryopithecus frickae*, type, left M₃, A.M.N.H. No. 19413 (after Gregory and Hellman, 1926, Pl. 10, Fig. A). Occlusal view. ×2

g2. *Dryopithecus darwini* Abel, left M₃ (after Abel, 1902, Fig. 3). Occlusal view. ×About 2

g3. *Paranthropus robustus* Broom, right M₃. Photograph from the cast. Occlusal view. ×2

Abbr.: c., cingulum; cp., pulp cavity; d., distal side; ed., entoconid; hd., hypoconid; l., lingual side; m., mesial side; md., metaconid; msd., mesoconid; pd., protoconid; ra., anterior root; rp., posterior root; s., sulcus of the root; st., style; tam., tuberculum mediale internum; t6, "tuberculum six"

12. Teeth of *Gigantopithecus blacki* von Koenigswald compared with those of other hominids and anthropoids

a. *Gigantopithecus blacki* von Koenigswald. Right upper molar. Occlusal view
   1. Photograph of the cast. ×1
   2. Drawing from the cast. ×2

b. Recent man, Siamese (A.M.N.H. No. V. L. 2448), right M². Drawing. ×3

c. *Sinanthropus pekinensis*, No. 41, left M². Occlusal view. Photograph of the original. ×2

d. Gorilla, male (C.R.L.P. No. 336), left M¹. Occlusal view. ×2

e1. Orang-utan, fossil, cave of Kwangsi (C.R.L.P.), left M². Drawing from the original. ×2

e2. Orang-utan, recent (C.R.L.P.), left M². ×2

f. *Dryopithecus germanicus* (Melchingen), left upper molar. Drawing from cast and photograph. ×2

g. *Sinanthropus pekinensis*, No. 40, left M². Drawing from the original. ×2

h. *Australopithecus africanus* Dart, left M¹ (see Weidenreich, 1937a, Fig. 115). Occlusal view. ×2

i. *Pithecanthropus robustus*, right M³. Photograph from the original. ×2

k. Recent man, infantile (prehistoric North Chinese), left M¹. Photograph. ×2

l. Recent man, Siamese (see b above), right M². Photograph. ×1

m1. Right M³ from Trinil. Attributed to *Pithecanthropus erectus*. Copy of Dubois' (1924) photograph. ×2

m2. Right M³ of a recent orang-utan. Copy of Gerrit S. Miller's Fig. 14, 1 (1923). ×2

n. *Gigantopithecus blacki*, right upper molar. Drawings from the cast. ×2
   1. Buccal view
   2. Lingual view
   3. Mesial view
   4. Distal view
   5. Basal view

Abbr.: b., buccal side; bdr., bucco-distal root; bmr., bucco-mesial root; co., crista obliqua; cp., pulp cavity; d., distal side; fb., flower-bud pattern of paracone; hy., hypocone; l., lingual side; lr., lingual root; m., mesial side; me., metacone; pa., paracone; pr., protocone; tf., clover-leaf pattern of metacone

TEXT FIGURES

1. *Pithecanthropus robustus* (*Pithecanthropus* Skull IV). Drawings from the original. ×⅓
a. Right side
b. Left side
c. From above
d. From behind
e. From below
f. Base from within

Abbr.: bp., basilar process of occipital bone (dislocated); ci., crista infratemporalis; cm., crista mastoidea; coe., crista occipitalis exterior; cpg., crista postglenoidalis; cs., crista supramastoidea; csg., crista sagittalis; fm., fossa mandibularis; id., incisura digastrica; ii., impressio plani nuchalis inferior; is., impressio plani nuchalis superior; ls., linea nuchae superior; plp., planum preglenoidale; pm., processus mastoideus; pp., processus pterygoideus; scp., spina cristae petrosae; sl., sutura lambdoida; spp., sinus processus pterygoideus; ssf., sutura sphenofrontalis; st., sulcus supratoralis; t., torus occipitalis; tp., torus angularis parietalis

2. *Pithecanthropus robustus* (*Pithecanthropus* Skull IV) maxilla. Drawings from the original. ×⅔
a. Right side
b. Left side
c. Frontal view
d. Floor of the nasal cavities and maxillary sinus

Abbr.: d., diastema; em., maxillary exostoses; fi., foramen incisivum; sm., sinus maxillaris; tm., tuber maxillare

3. Interporial coronal craniograms superimposed on the po-po axis. ×½
—— *Pithecanthropus robustus*
- - - *Pithecanthropus erectus* (Skull II)
. . . *Sinanthropus pekinensis* (Skull XII)
- . - . - Rhodesian skull
Abbr.: l., left side; lt., linea temporalis; r., right side; ss., sutura squamosa

4. *Pithecanthropus erectus* (Skull II). Drawings from the original. ×½
a. Norma lateralis sinistra
b. Norma lateralis dextra
Abbr.: im., incisura mastoidea; pm., processus mastoideus; t., torus occipitalis; tp., torus angularis parietalis

5. *Pithecanthropus erectus* (Skull II). Drawings from the original. ×½
a. Norma frontalis
b. Norma occipitalis
Abbr.: csg., crista sagittalis; lt., linea temporalis; t., torus occipitalis

6. *Pithecanthropus erectus* (Skull II). Drawings from the original. ×½
a. Norma verticalis
b. Norma basilaris
Abbr.: b., bregma; csg., crista sagittalis; fp., foramen parietale; l., lambda; lt., linea temporalis; tp., torus angularis parietalis

7. *Pithecanthropus erectus* (Skull II). Horizontal section through the cast of the skull cap. ×½
Abbr.: p., pyramis; sc., sutura coronalis; sl., sutura lambdoidea

8. *Pithecanthropus* Mandible B. Drawings from the original. ×1
a. Buccal view
b. Lingual view
c. Basal view
Abbr.: C, alveolus of canine; I₂, alveolus of lateral incisor; P₁, alveolus of first premolar; fd., fossa digastrica; tma., tuberculum marginale anterius

9. *Sinanthropus pekinensis*, right P₁ (No. 82; see Weidenreich, 1937a, Fig. 82). Drawings from the original. ×2
a. Buccal view
b. Mesial view
c. Occlusal view

10. Millimeter graph showing the size of the lower teeth (P₁, P₂, M₁, M₂) as expressed in the rectangles (length×breadth) of the crowns. The figures at the left indicate the respective values of the rectangles in square millimeters. ×⅓
a. Left side: recent man ——; *Sinanthropus pekinensis* - - -; Sangiran Mandible of 1939 . . . .
b. Right side: Heidelberg mandible - - -; female gorilla . . . . ; *Meganthropus* ——.

11. Alveolar and basal arches of the *Meganthropus* mandible compared with those of a female gorilla (a), *Sinanthropus* Mandible G I (b), Heidelberg mandible (c), and male Australian aborigine (d). The *Meganthropus* arches are indicated by continuous lines and shading, the others by broken lines. ×⅓. (Alveolar and basal arches are drawn according to Virchow's instructions, 1916, 1920, and are superimposed on the mid line and the transverse "postlacteon" line drawn in front of M₁, according to Bolk, 1926b.)
Abbr.: ba., basal arch.; pl., transverse "postlacteon" line

12. Mid-sagittal sections through the symphysis of the *Meganthropus* mandible (a) compared with anthropoids, recent (b–d) and fossil (e–j), and hominids, recent (o, p) and fossil (k–n). ×1.
   Diagram of *Meganthropus* indicated by a continuous line, the others by broken lines. All the diagrams are oriented on the alveolar plane (indicated by the light horizontal line) and superimposed on the incision (i). The incision-gnathion line (i–gn) represents the axis of the front part of the mandible; the angle it forms with the alveolar plane is the angle of inclination. The line from fs (foramen spinosum) to the axis (i–gn) indicates the level of the foramen spinosum.
a. *Meganthropus:* the part above the oblique broken line is restored
b. Male gorilla (A.M.N.H. No. 54091)
c. Male orang-utan (C.R.L.P.)
d. Male chimpanzee (C.R.L.P.)
e. *Dryopithecus pilgrimi* (after Gregory and Hellman's restoration, 1926)
f. *Dryopithecus fontani* Lérida (after Smith Woodward's cast, 1914)
g. *Ramapithecus brevirostris* (cast)
h. *Sivapithecus himalayensis* (cast)
i. *Paranthropus robustus* (after Broom, 1938)
j. Sangiran Mandible of 1939
k. Piltdown mandible (after McGregor's restoration, 1910)
l. *Sinanthropus* Mandible HI
m. Heidelberg mandible (after Schoetensack, 1908)
n. Krapina Mandible H (after cast)
o. Recent man (male Australian aborigine)
p. Recent man ("Old Man," upper cave of Choukoutien)

13. Acromegalic human mandibles
a. Mandible of an English woman (after Geddes, 1911, Fig. 11). ×About ⅓
b. Mandible of the Irish giant (Patrick Cotter). (after Keith, 1925, Fig. 148). ×About $\frac{5}{12}$
*Abbr.:* c., condylion; gn., gnathion; go., gonion

14. Deformed mandible of a Melanesian (after Gullberg and Burkitt, 1925, Fig. 2). Norma lateralis sinistra. $\times\frac{1}{2}$

15. Deformed mandible of a Melanesian, viewed from below (after Gullberg and Burkitt, 1925, Fig. 1). Not to scale

16. Cross-section through the mandibles of *Meganthropus* (a), the Melanesian of Figs. 14 and 15 (b), and a normal European (c). $\times 1$. b and c after Gullberg and Burkitt, 1925, Fig. 4

    Abbr.: cm., canalis mandibularis

17. Sketch of the occlusal surface of the Sangiran Mandible of 1939. $\times 1$

    Abbr.: al_1, alveolus of the posterior root of P_2; al_2, alveolus of the anterior root of P_2; al_3, alveolus or washed-out bone structure; ard., distal area; arm., mesial area; ja., jugum alveolare; r., root of canine (?)

18. Sketch of the occlusal surface of a male orang-utan (A.M.N.H. No. 124). C_1, P_1, and P_2 removed to show the position and form of their alveoli. $\times 1$

19. Right M_1 of a juvenile male gorilla (C.R.L.P. No. 336). Occlusal view. $\times 2$

    Abbr.: d., distal side; ed., entoconid; hd., hypoconid; md., metaconid; ms., mesoconid; prd., protoconid

20. Right M_2 of a juvenile male chimpanzee (C.R.L.P. No. 381). Occlusal view. $\times 2$

    Abbr.: d., distal side

21. Left M_1 of a male orang-utan (C.R.L.P. No. 231). Occlusal view. $\times 2$

    Abbr.: m., mesial side

22. Right M_1 of *Sinanthropus pekinensis*, No. 98. Occlusal view. $\times 2$

    Abbr.: dw., deflecting wrinkle; tam., tuberculum accessorium internum

23. Subfossil recent man from the volcanic ashes of the Sangiran District in Java. Upper molar. Occlusal view. $\times 2$

    a. Intact enamel with a normal system of wrinkles

    b. The same tooth with the exposed dentine after removal of the enamel

24. Millimeter graph showing the size of the M_3 and M^1 of *Gigantopithecus, Meganthropus, Pithecanthropus robustus* and *erectus, Sinanthropus,* and recent man. $\times\frac{1}{2}$

25. Millimeter graph showing the size of the upper and lower teeth of fossil and recent hominids as represented by their rectangles (length $\times$ breadth). $\times\frac{1}{2}$

    a. — *Pithecanthropus robustus:* upper teeth
       - - - *Meganthropus:* lower teeth
       . . . *Pithecanthropus erectus* (Mandible B): lower teeth

    b. — *Sinanthropus:* upper teeth (average)
       . . . *Sinanthropus:* lower teeth (average)

    c. — Recent man: upper teeth (average)
       . . . Recent man: lower teeth (average)

26. Outlines of the bodies of the mandibles of Kedung Brubus (—), *Pithecanthropus* Mandible B (- - -), *Meganthropus* reconstructed (- . -), and *Gigantopithecus,* constructed on the basis of the size of M_3 (. . . .). $\times 1$

27. Map of southeast Asia and Indonesia showing the distribution of the Sino-Malayan fauna. The localities from which it has been recovered are indicated by solid squares. The arrows indicate the direction of its expansion

    1. Choukoutien
    2. Pits of Yenchingkou
    3. Cave near Hsingan
    4. Hoshang cave
    5. Mogok caves
    6. Long-son cave
    7. Tam-hang
    8. Trinil beds of Trinil and Sangiran

28. Mid-sagittal section through the head of an adult male chimpanzee (a), and an adult male European (b) (after Weidenreich, 1934, Figs. 26 and 29). $\times\frac{1}{2}$

    Abbr.: gg., M. genioglossus; gh., M. geniohyoideus; mh., M. mylohyoideus; p., platysma; sm., spina mentalis; tti., torus transversus inferior ("Basalplatte")
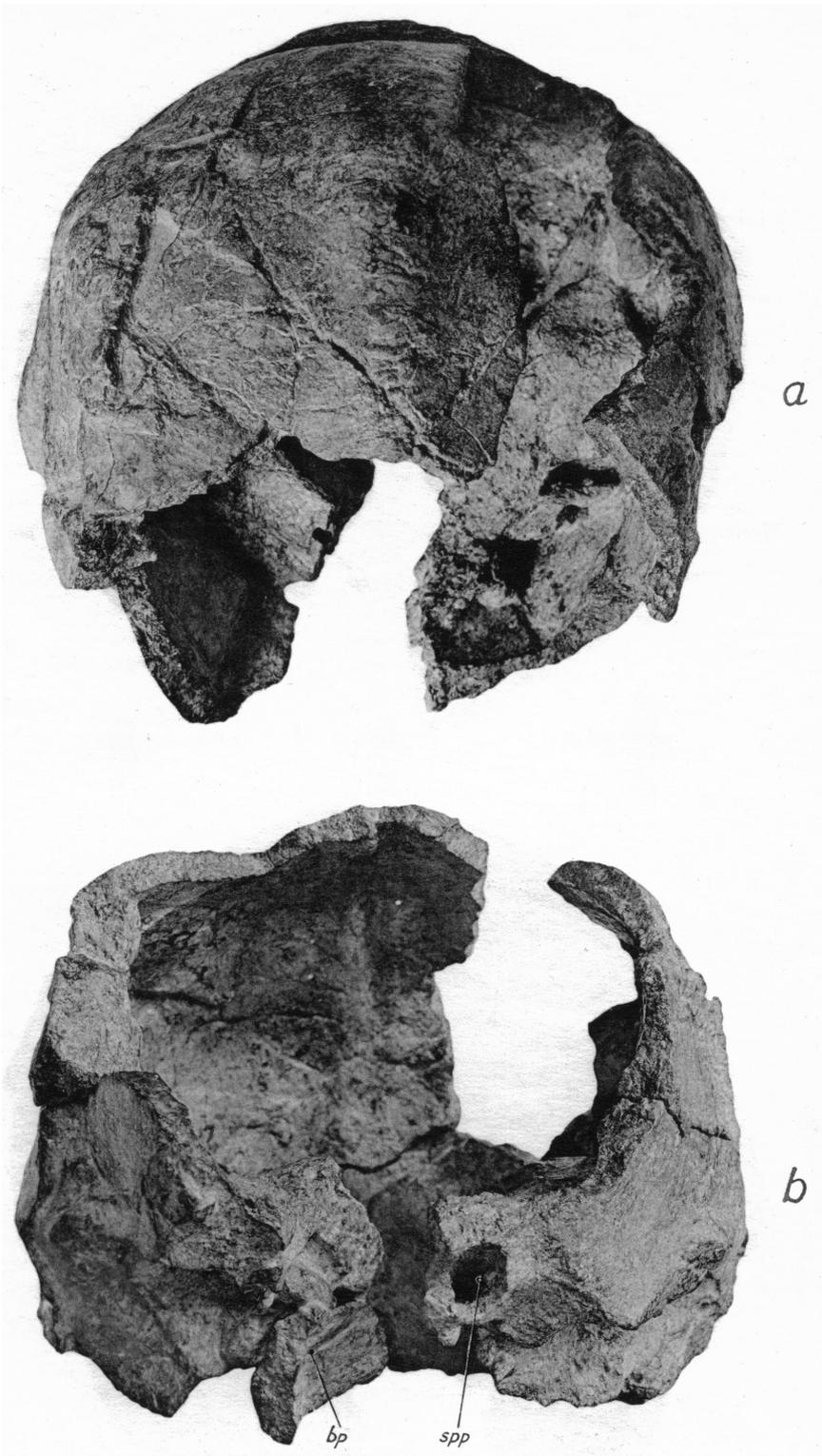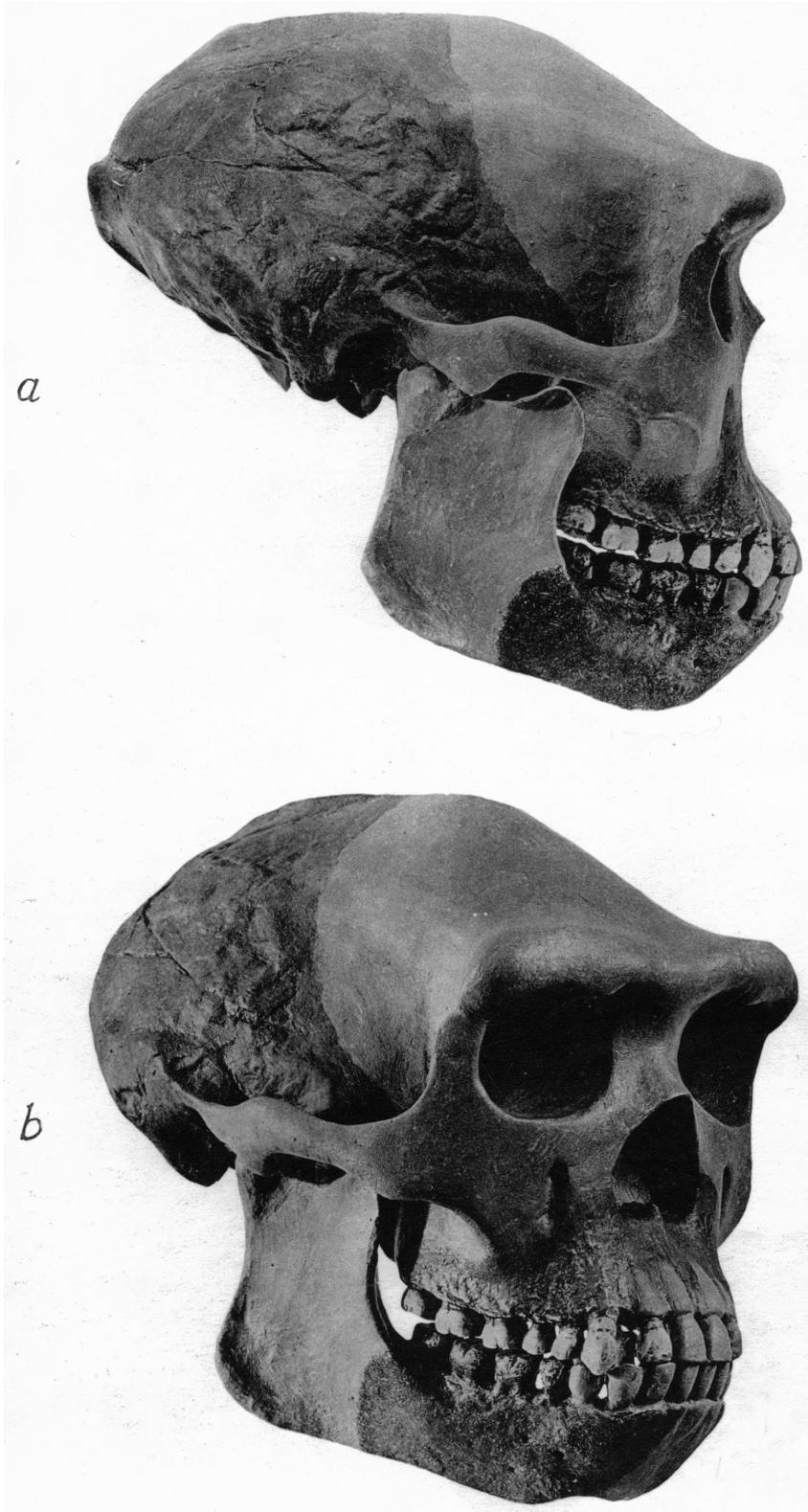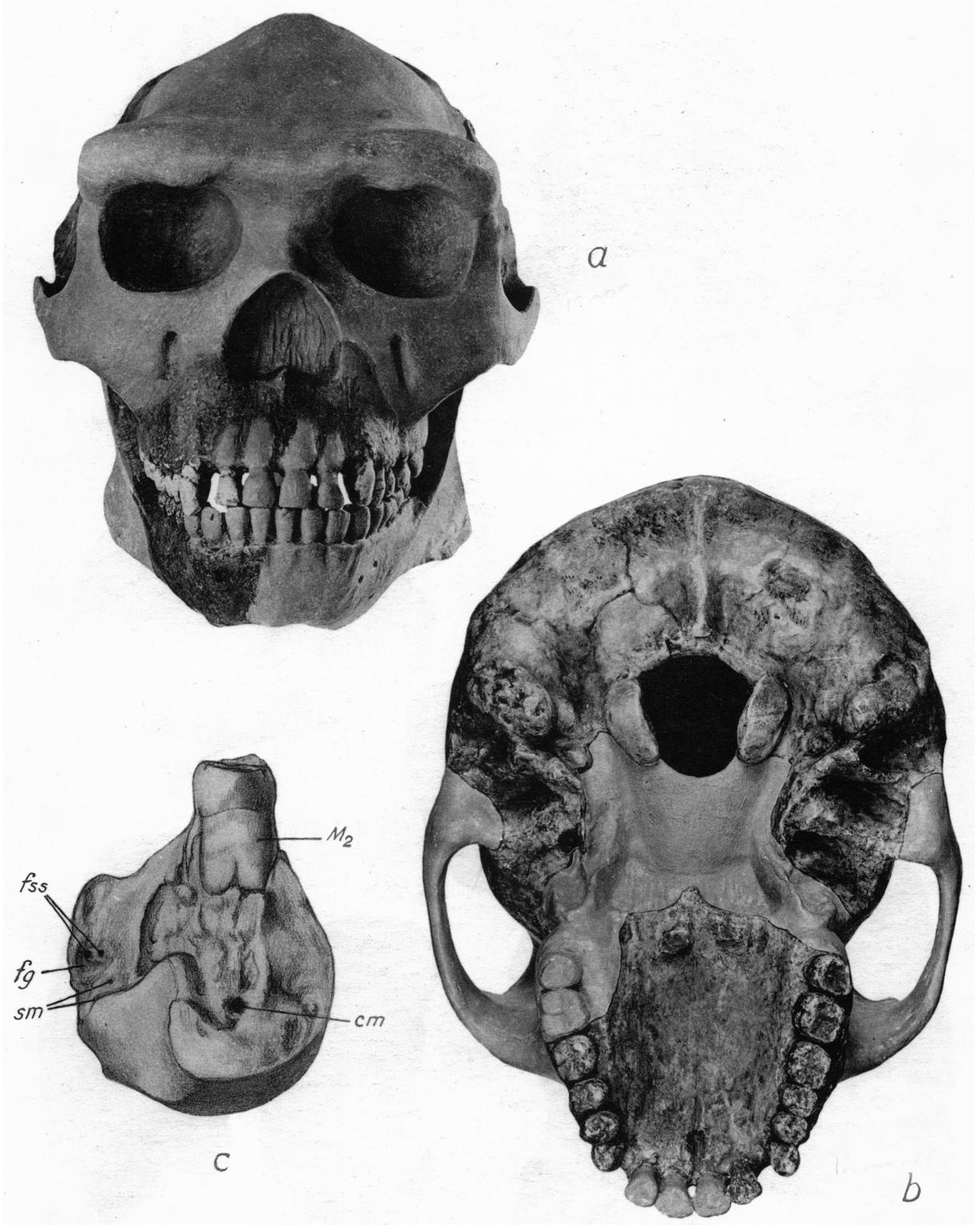
Skull of *Pithecanthropus robustus* (*Pithecanthropus* Skull IV)
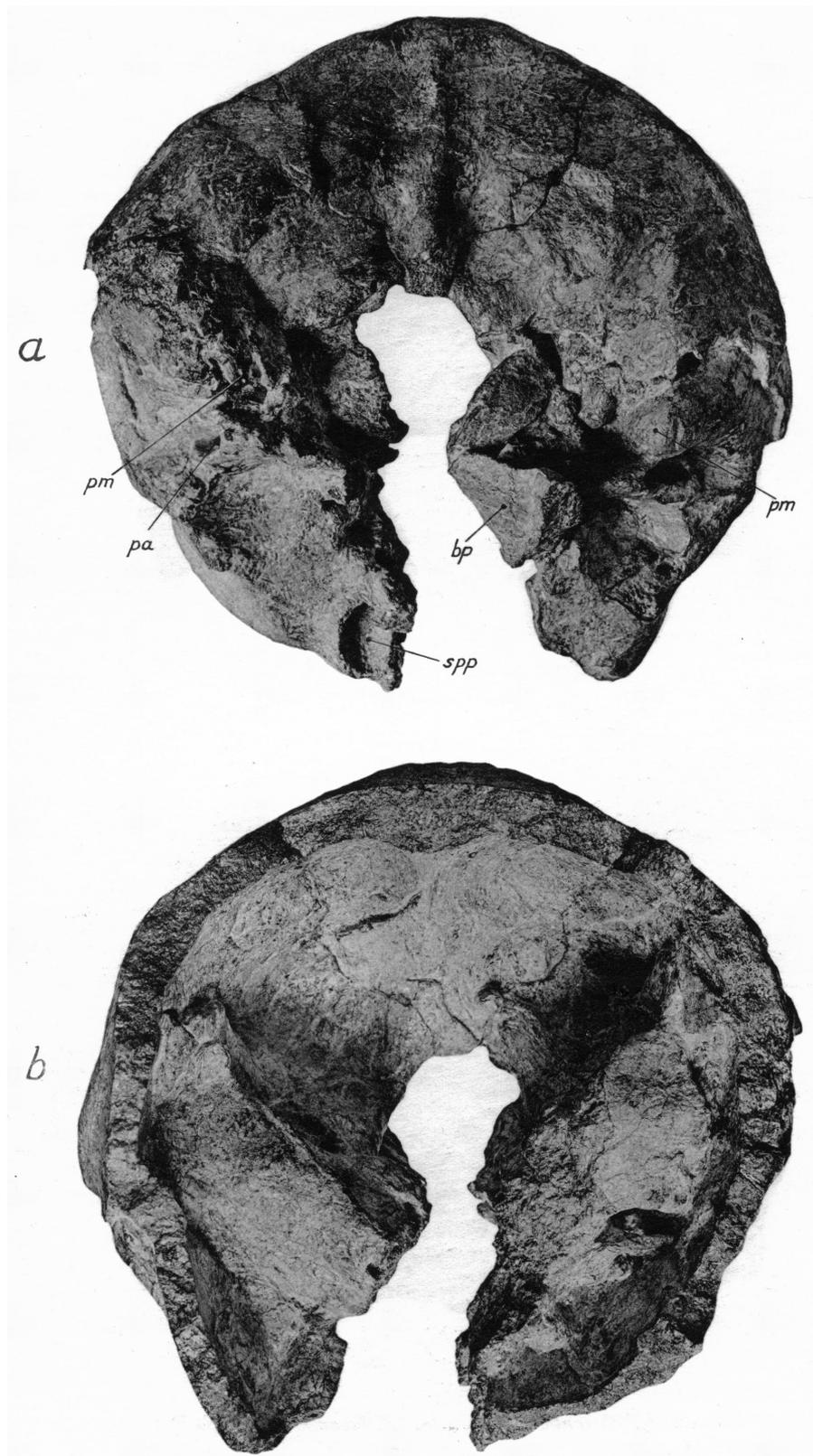
Skull of *Pithecanthropus robustus* (*Pithecanthropus* Skull IV)
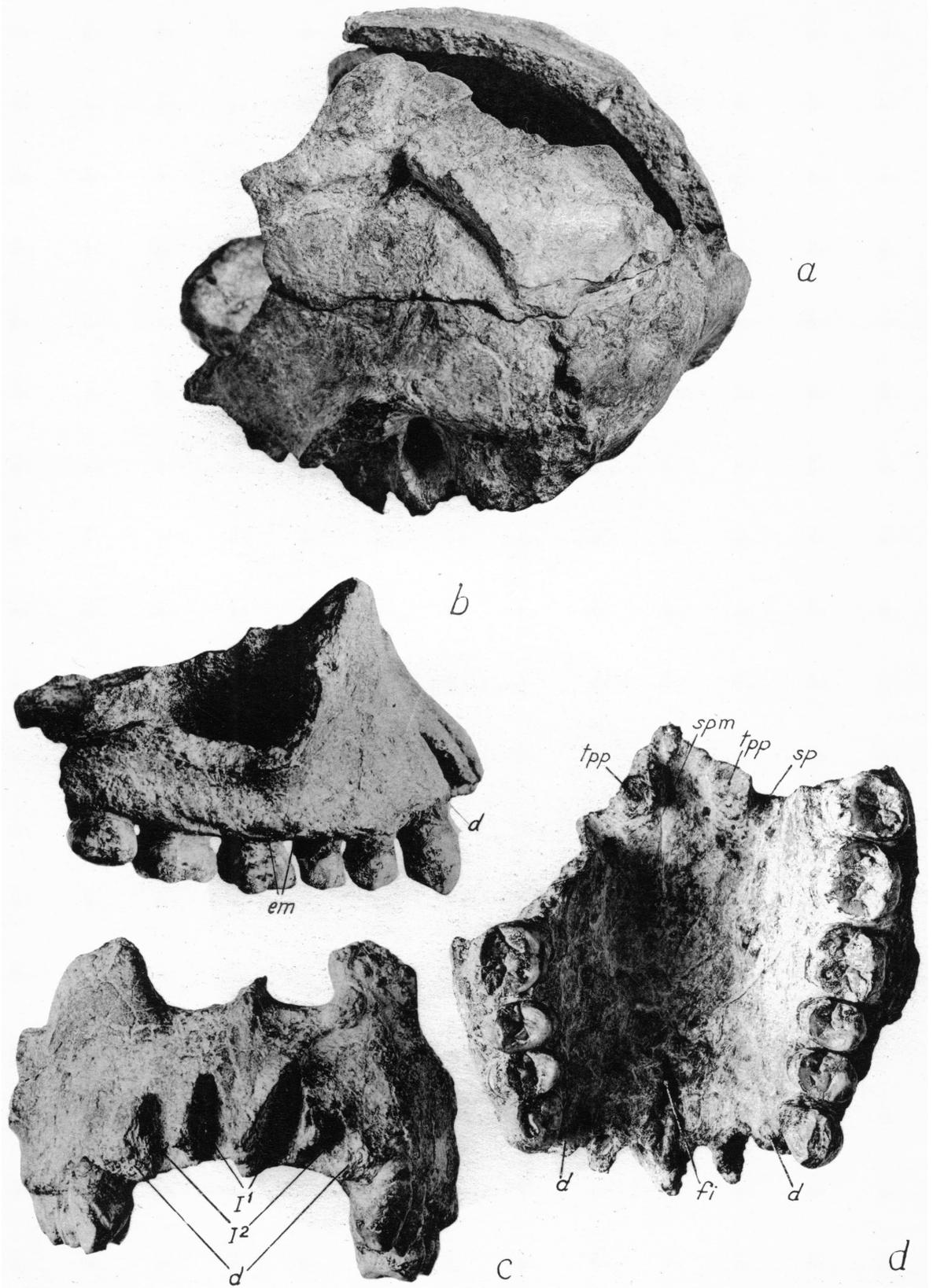
Skull of *Pithecanthropus robustus* (*Pithecanthropus* Skull IV)

Skull of *Pithecanthropus robustus* (*Pithecanthropus* Skull IV), reconstruction of the calvaria combined with a reconstruction of the *Pithecanthropus* (*erectus*) Mandible B
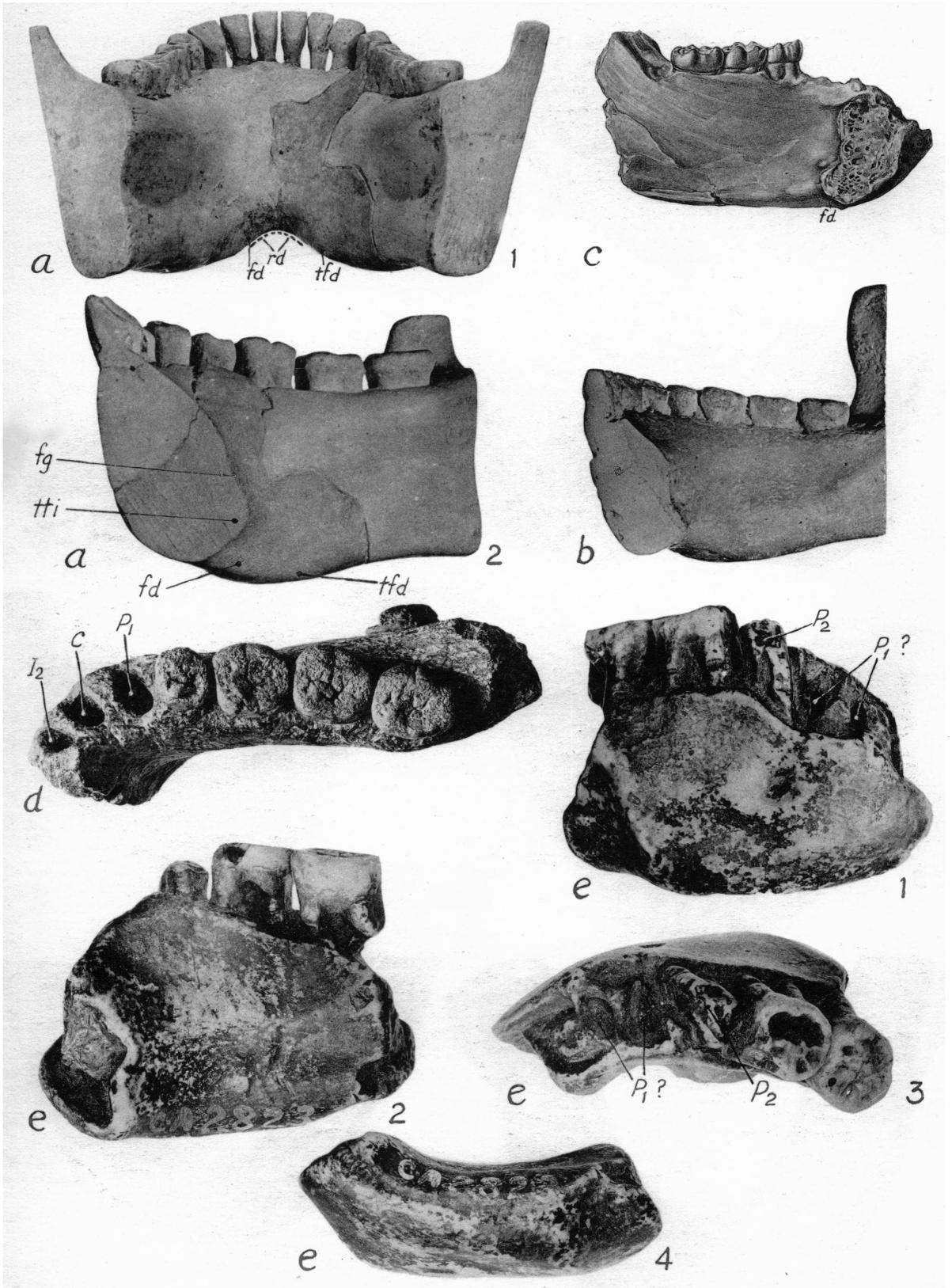
Skull of *Pithecanthropus robustus* (*Pithecanthropus* Skull IV), reconstruction as in Pl. 4, and mandible of *Meganthropus palaeojavanicus* von Koenigswald
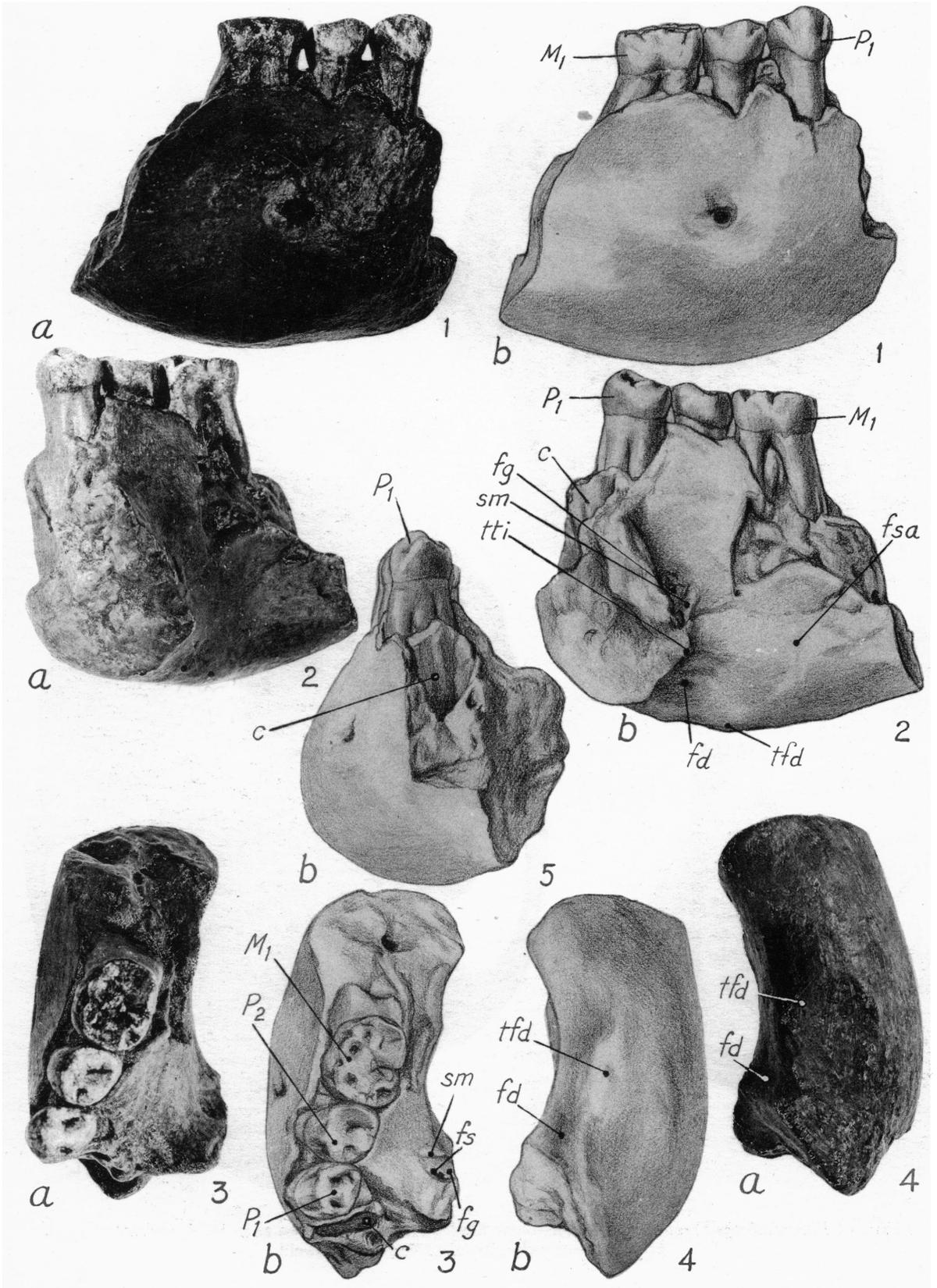
Mandible of *Meganthropus palaeojavanicus* von Koenigswald
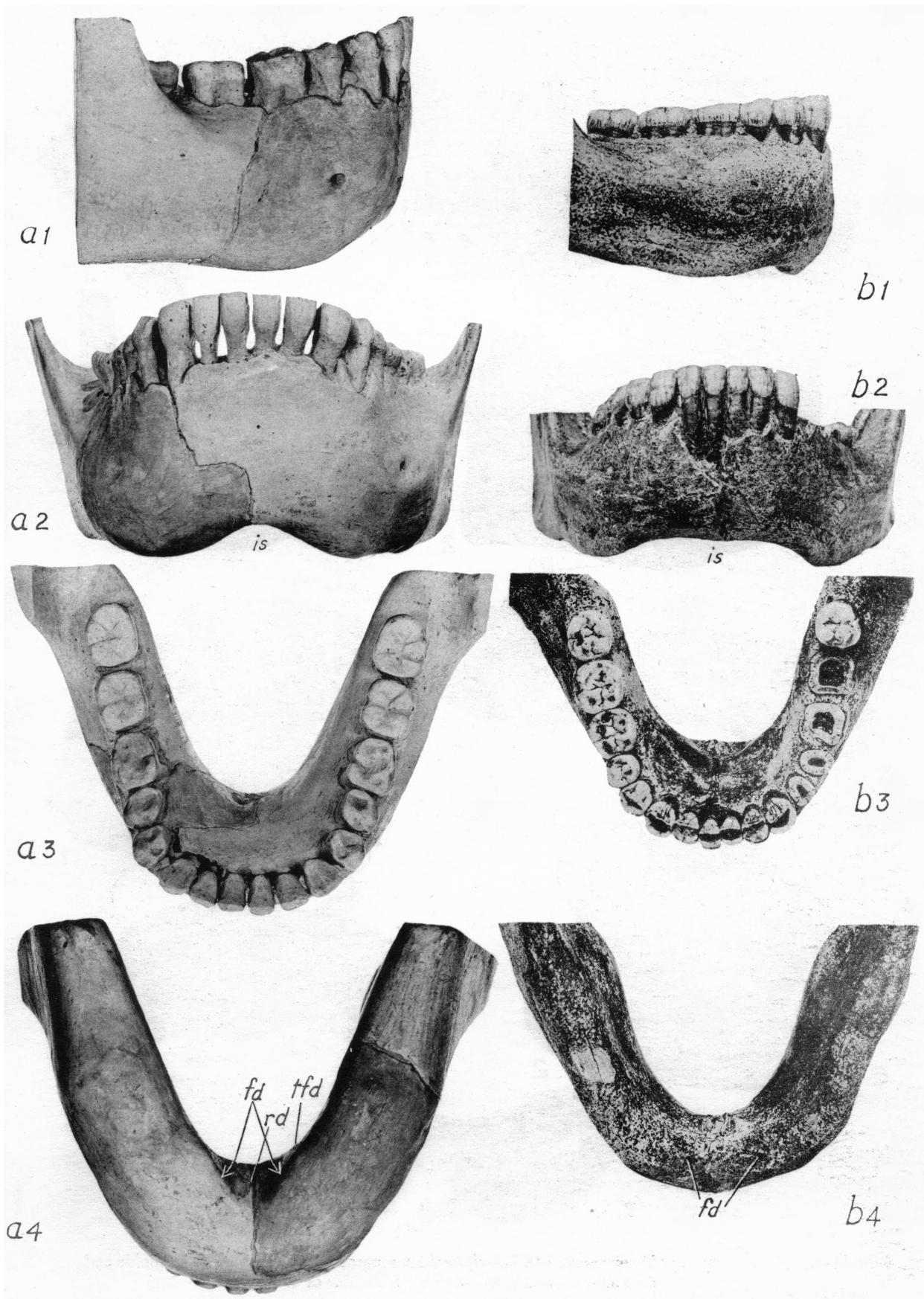
Mandibles of *Meganthropus palaeojavanicus* von Koenigswald, and Heidelberg Mandible

Mandible of *Meganthropus palaeojavanicus* von Koenigswald compared with that of other hominids and
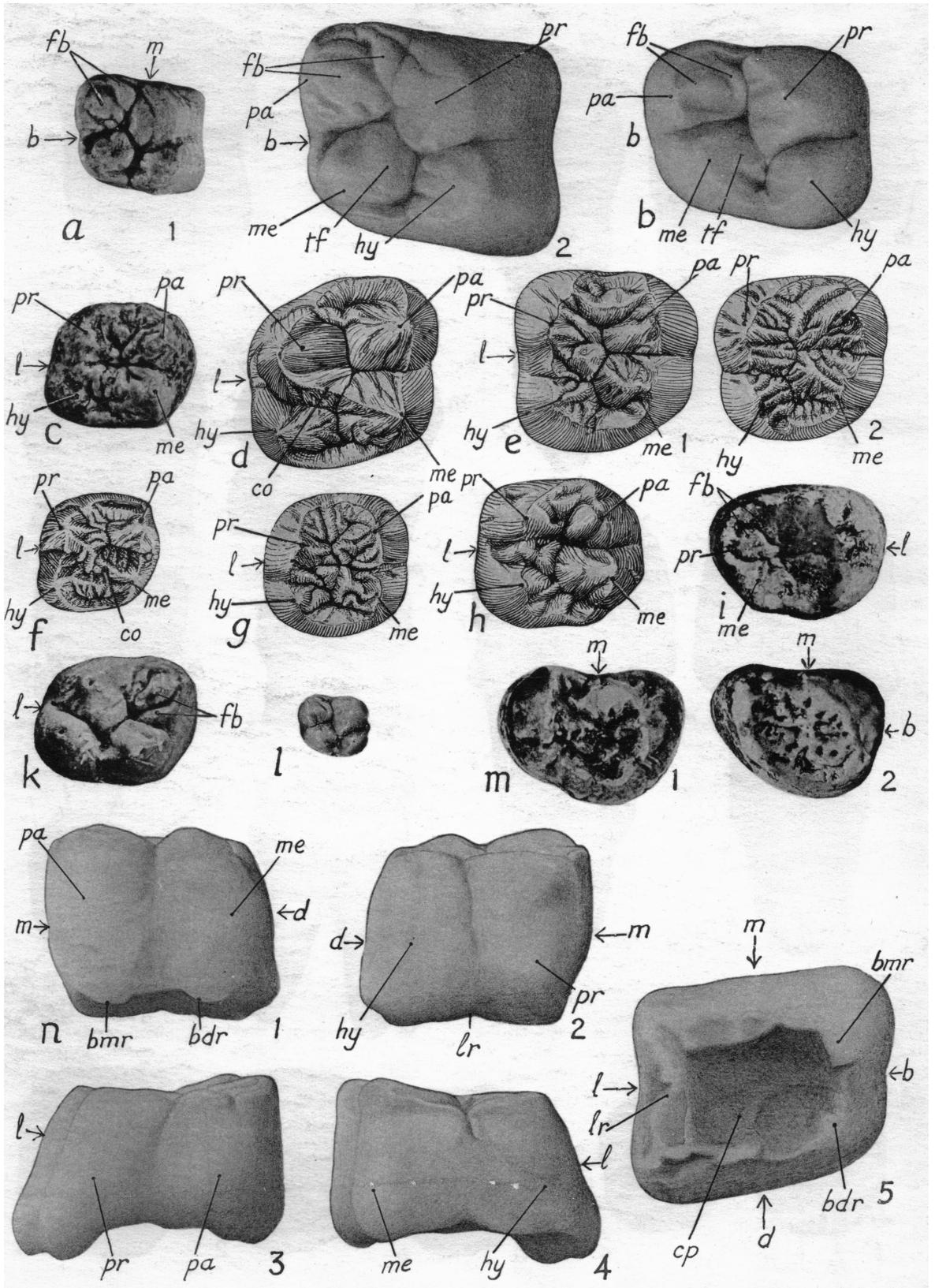anthropoids, and with Sangiran Mandible of 1939
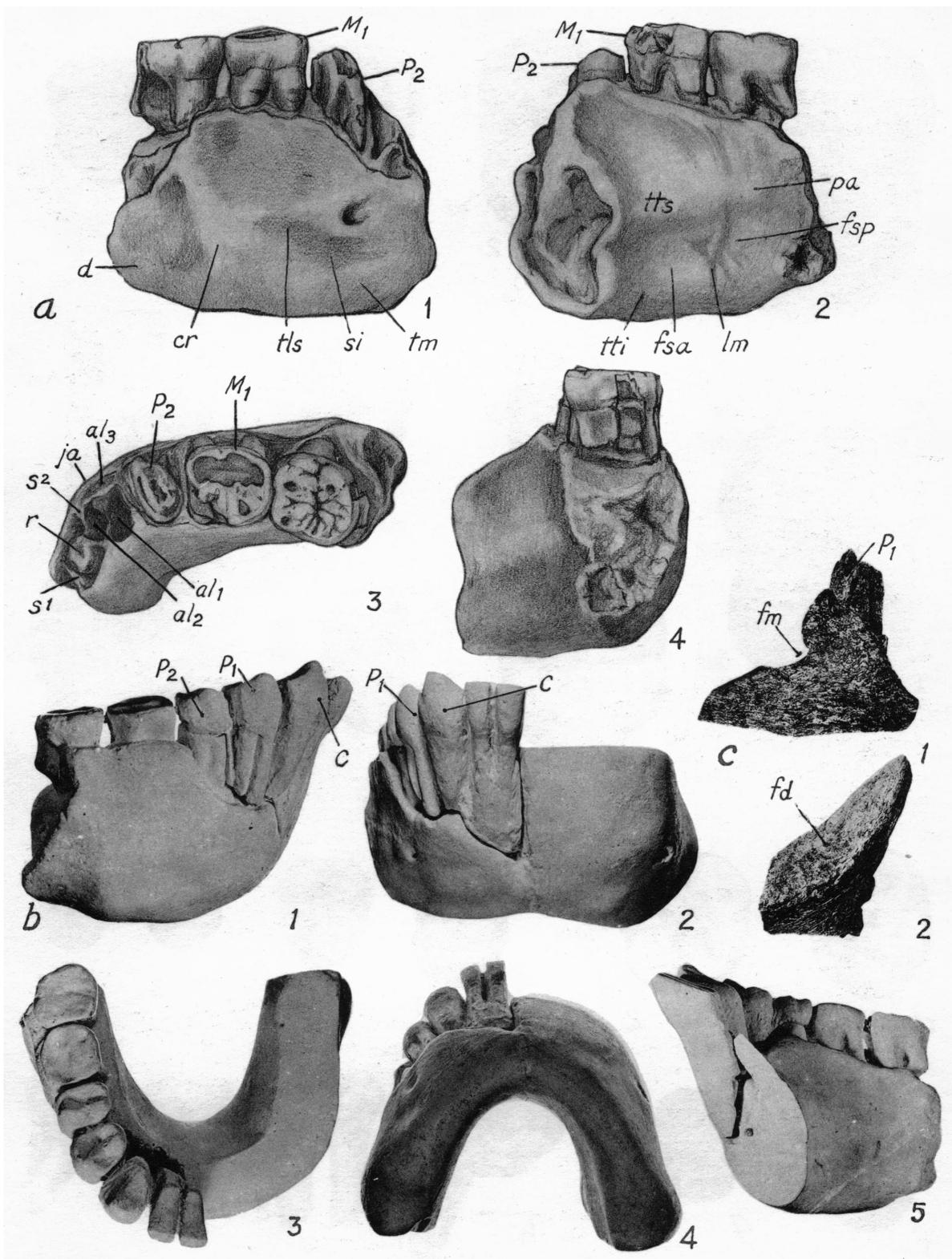
Sangiran Mandible of 1939, and Kedung Brubus Mandible
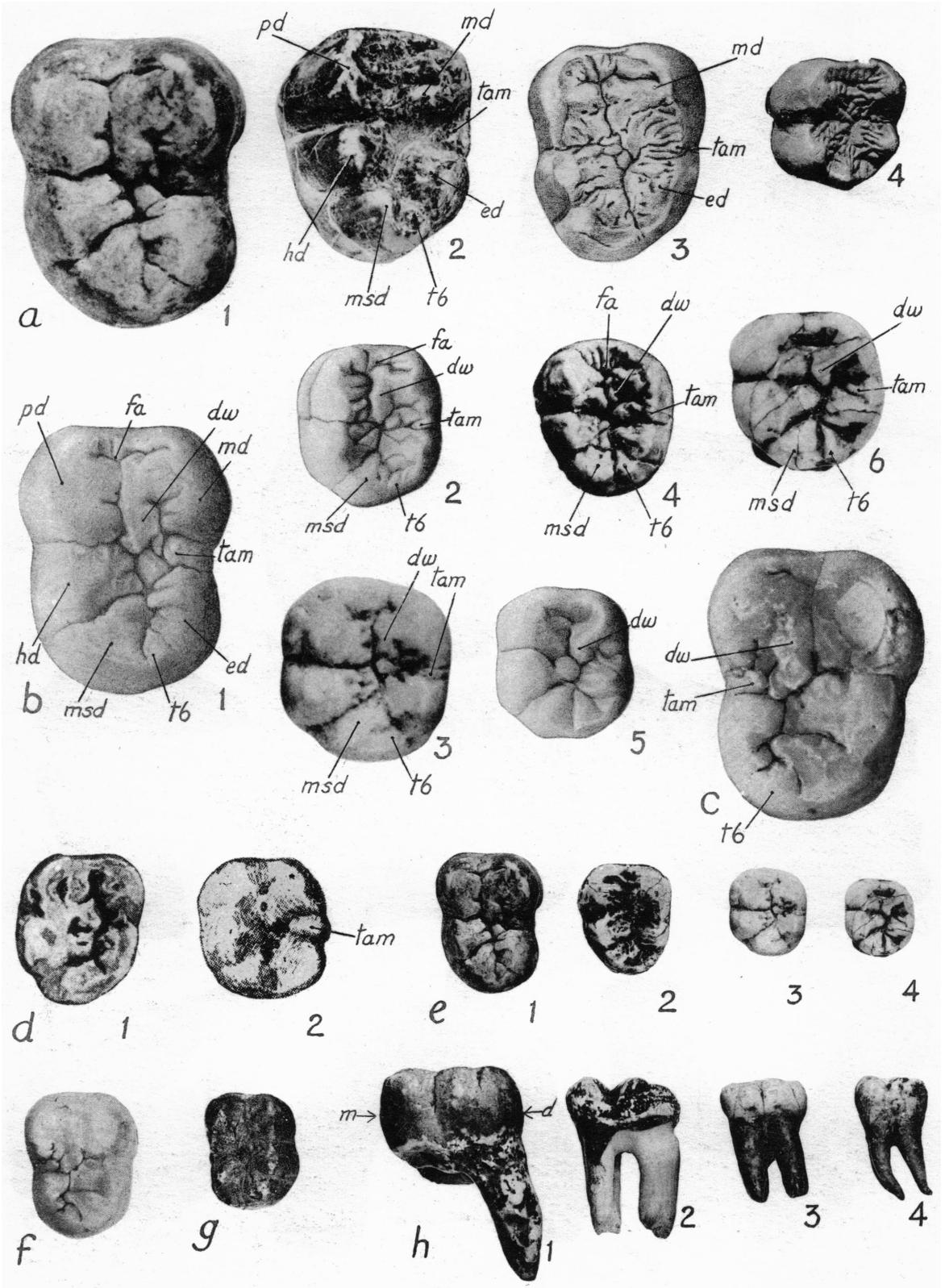
Teeth of *Gigantopithecus blacki* von Koenigswald compared with those of other hominids and anthropoids
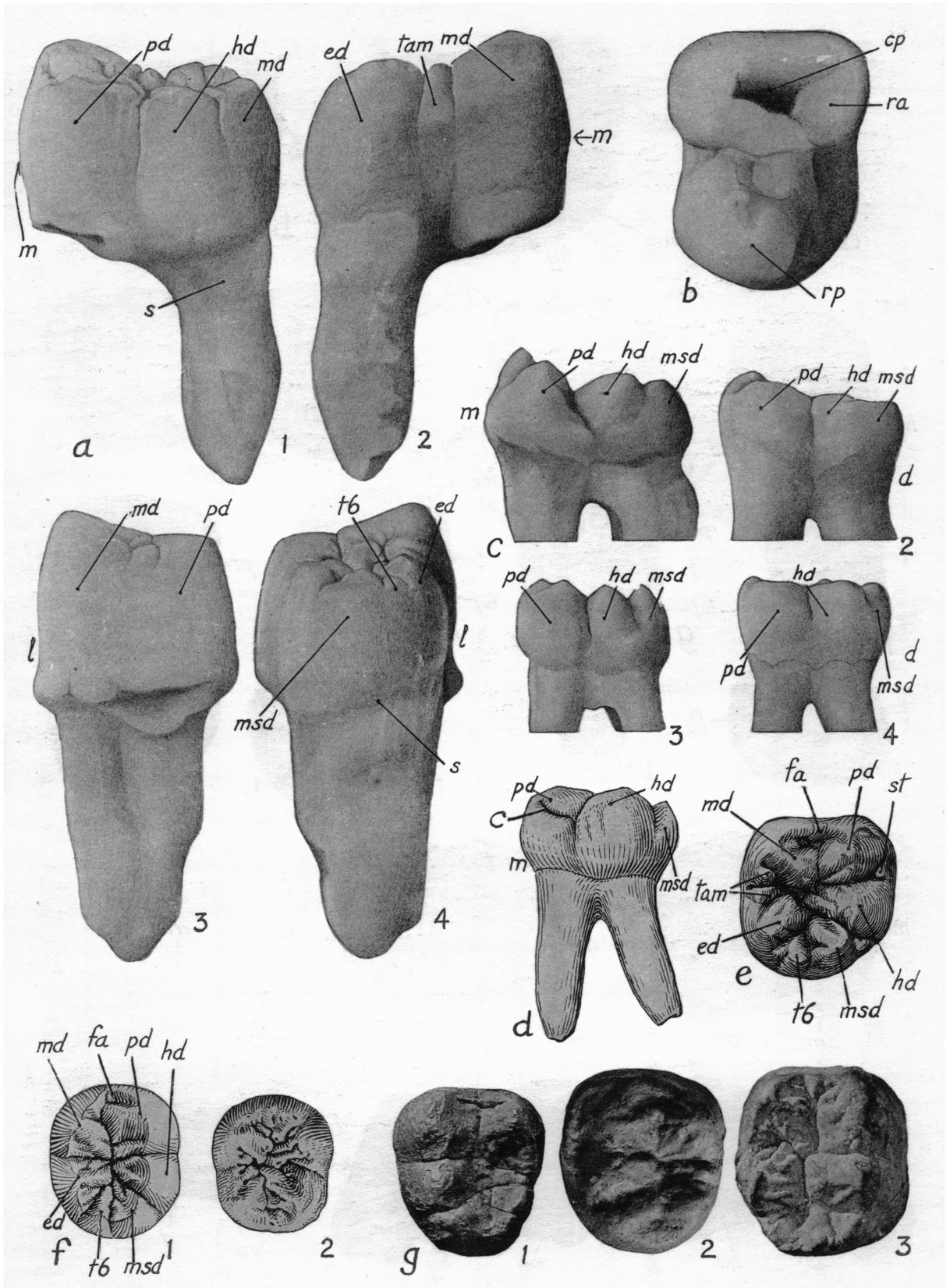
Teeth of *Gigantopithecus blacki* von Koenigswald compared with those of other hominids and anthropoids

Teeth of *Gigantopithecus blacki* von Koenigswald compared with those of other hominids and anthropoids

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OF THE

AMERICAN MUSEUM OF NATURAL HISTORY

Volume 40