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Palæontologia Sinica

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THE DENTITION OF *SINANTHROPUS PEKINENSI*
A COMPARATIVE ODONTOGRAPHY OF THE HOMINIDS

BY

FRANZ WEIDENREICH

ATLAS WITH PLATES I-XXXVI AND 49 DIAGRAMS

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PALÆONTOLOGIA SINICA

THE DENTITION OF *SINANTHROPUS PEKINENSIS*:
A COMPARATIVE ODONTOGRAPHY OF THE HOMINIDS

BY

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With Tables I-XXVII and in separate volume an Atlas containing
Plates I-XXXVI and 49 Diagrams

Peiping, 1937

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INTRODUCTION

> "The crown of the human tooth even in its minute details represents but little that is fortuitous. It is resultant of inherited ancestral conditions, modifying further by evolution and involution."
>
> Hrdlicka (1924, p. 123)

The theory that man developed from a primitive primate type is probably now generally accepted. The position, however, of this type within the primate class and its relationship to other members of the same order is now, more than ever, a problem of considerable dispute. There are two chief views the principles of which have been most clearly evolved by the well known debate between Osborn and Gregory. According to Gregory the evolution of man must have undergone a real anthropoid stage, while Osborn most strongly opposes such a conception and claims that man must have been derived directly from a prosimian-like form without any close relation to anthropoids. In my opinion the latter conception is due to a misunderstanding on the part of Osborn, for it is evident that man in the course of evolution, whatever the zoological character of its earliest type may have been, has had to pass through a stage of organisation corresponding to that of anthropoids and that therefore its relationship to the latter must be closer than to other primate groups. This does not imply that all the physical conditions of man were in complete accord with those of gorilla or chimpanzee or orang or those of any of their direct ancestors. An anthropoid regarded from a purely zoological standpoint is nothing else but a special primate occupying the highest position because of its organisation in the order of Catarrhinæ and clearly distinguishable by its characteristics from the lower representatives of the same group. According to zoological classification based exclusively on morphological, general and special features of living primates and going back to Linæus even man of today approaches closer to the anthropoids than to any other group of primates. This fact has been fully presented and ascertained by Huxley (1863) who stated: "Whatever system or organs be studied, the comparison of their modifications in the ape series leads to one and the same result—that the structural differences which separate Man from the gorilla and the chimpanzee are not so great as those which separate the gorilla from the lower apes." Since then many additional evidences of the correctness of Huxley's conclusion have been presented. Thus, there is not the least doubt that since this is true for present-day man and apes, it must be all the more valid for representatives of the phylogenetic line.

One fact has undoubtedly contributed considerably towards the above mentioned misunderstanding, namely that the differences between fossil hominids such as Neanderthal and recent man have proven in some details to be not as great as was generally expected. This is especially true of the dentition. In this respect Werth's perception (1921/28) is of symptomatic significance. On the basis of his studies of the Heidelberg mandible, he came to the conclusion that there are nowhere decisive differences between fossil and recent man: with respect to all characters of the dentition fossil man falls within the range of variation of living man, and futhermore the result is always the same and points to a very archaic—one may incline to say—Early Tertiary form of human dentition.

In the introduction to my Tokyo lecture (1936a) I warned against confusing morphological and geological facts when determining fossil human findings, a confusion which has played a great and harmful role in the history of many of the discoveries. In the case of the Heidelberg mandible, the geological age of which at first was taken to be great, many investigators were led to assume its distinct antiquity, and thus to assume a correspondingly primitive morphological character of the fossil in all its details. Such a conception was further supported by the bulkiness of the jaw in contrast to the size and features of the dentition. Thus the Heidelberg mandible was described and attributed to a "preneanderthaloid" and its teeth were considered to be typical for all primitive hominids. Neither of these interpretations stands firm when scrutinized more closely. As to the mandible itself I was able to demonstrate (1936b) that in spite of its bulkiness as a whole some of its features reveal an already rather advanced character. In regard to the teeth this report will prove that they are even further removed from the original interpretation than the jaw.

In this connection nomenclature deserves particular attention. It is common usage to term "pithecoid" any features of man which more or less resemble those of apes. R. Virchow and more recently Adloff (1909a, 1937) are both against the use of such a term. The latter author believes that it is not permissible to term a characteristic which is still existent in recent man as pithecoid, but in my opinion such an objection is not valid: firstly, the term "pithecoid" does not imply more than being ape-like, secondly the objection is apparently based on the assumption that a fossil form which in some respects resembles that of recent man is entitled to be determined as hominid. An excellent example of how far Adloff (1932) ventures in this respect is to be found in his consideration of *Australopithecus* as representing a real hominid, based only on certain features of its dentition. By such a process we may find ourselves in the rather grotesque situation of having one investigator who terms the hominids as pithecoid and another who considers the apes hominids. It goes without saying that such a controversy expresses only the personal view of the various authors concerned but does not touch the fundamental principle. The former investigator judges zoological characters of a given type exclusively by the momentary morphological appearance, while the latter deduce it from its potentialities of the subsequent evolution: hence the debate, was man derived from apes or were apes derived from man?

When considered in their true aspect, it is evident that the differences are not at all basic, for they at least demonstrate, perhaps better than other facts, a close connection between hominids and anthropoids. The lower we descend in the phylogenetic line the less possible it becomes to determine where one ends or where the other begins. The discovery of *Sinanthropus,* however, provided a new landmark. In future it will be impossible to pronounce the teeth of recent man as being the really primitive ones and those of the anthropoids as the only specialized and to deduce therefrom a fundamental contrast between man and anthropoids.

It is self-evident that a morphological peculiarity may be retained for a long period. We shall only determine its loss if we trace back to the part of the main stem where the actual differentiations took place. In connection with man a great error was conceived in the belief that the stage of evolution was not as remote as it actually is. If this erroneous assumption is corrected and furthermore, if the concept is abandoned that geological age must be taken under any circumstances to be tantamount to the age of evolution, all existing difficulties will be overcome immediately.

The decisive factors in each attempt at tracing the line of human evolution are found in palæontological evidences. Nowhere can it be demonstrated as clearly as on the dentition. I do not intend to enter into a discussion of the various hypotheses of the phylogenetic development of the dentition since such an attempt would be far too removed from my present task. However, I cannot pass over in silence Bolk's "dimere" theory (1913/14) for he preferred to select his proofs from peculiarities pertaining to the dentition of recent man. Most of the special features he selected such as those of the incisors, canines and premolars are secondary alterations of primarily much more complicated patterns and remote from the theoretically supposed prototypes. Palæontology of hominids reveals the fact in all cases that it is wrong to consider without reservation transitory ontogenetic features as phylogenetic realities.

Bolk made the same error in his attempt (1926) at explaining the development of the human chin chiefly on the basis of ontogenetic studies in which he failed to include fossil hominid material, an omission which I have pointed out elsewhere (1936b). The same applies to his so-called theory of foetalization (pedomorphism). Bolk considered the specific character of the process of human phylogenetic evolution to be a gradual fixation of transitory ontogenetic stages into persistent features. According to him the preponderance in the size of the brain of recent man in comparison with that of the apes is only a consequence of the fixation of an early ontogenetic state in which the brain size always preceded the other parts of the head and the body. In all monkeys and apes the brain should accordingly show the tendency of a propulsive growing a process which stopped rather early in the human ontogenetic development while in apes it continued unchecked. The equality of that tendency in both groups should be inferred from the fact that the foetus and young individuals of apes possess a more vaulted and therefore more human-like forehead than the adults. Incidentally, a similar deduction of the same phenomenon has recently been made by Schindewolf (1936) following Naeff (1933) so as to demonstrate that evolution is only caused by fortuitous alterations of genes which should be manifest during embryonic life. Bolk as well as Schindewolf believe the difference in appearance of infantile and adult skulls of apes and the closer similarity of the former with the skull of recent man to prove that anthropoids and hominids have nothing in common. As has been shown already thirty years ago by Schwalbe (1906), while opposing a similar argument brought by Ranke and Kohlbrügge, the fundamental error of those considerations consists in taking a juvenile character for comparison instead of an adult. In the case in question it is particularly wrong because the jaw and the teeth compose the decisive factors in the definite formation of the outer structure of the skull; both jaw and teeth, however, gain their permanent size relatively late in the normal course of development and in consequence the actual outer appearance of face, forehead and brain case can only be manifest in fully developed adult individuals. There is no justification in singling out, more or less at random, a certain stage of ontogenetic evolution, and in claiming that such and no other stage is the most suitable for comparative purposes. In addition it is to be noted that it is a well known fact that not only primates but all mammalians bear a closer resemblance to each other the younger their stage of development and this is especially true for the brain which precedes considerably all other organs in development. All young mammalians have a much more bulging forehead than when fully developed. However, apart from these arguments there remains one fact which hitherto escaped attention, namely that apes despite their more vaulted forehead in juvenile stages do not in reality possess a correspondingly better developed frontal lobe of the brain towards the end of the first dentition as is true of man of the same age. The proportions between the frontal lobe and other parts of the brain are exactly the same as in the adult stage. This condition clearly proves that the external appearance of the forehead feigns the existence of essentital differences which actually are not present but are only the result of temporary under-development of other regions.

At any rate the attempt to reconstruct the course of human evolution on the basis of ontogenetic data derived from recent primates seems, in my opinion, to be out of place if fossil remains are available which have provided us with certain real stages of phylogenetic evolution. Such material is now at hand. It represents a continuous line leading from *Sinanthropus* to recent man (Weidenreich, 1937 a,b). Viewed as a whole and in detail there is not the slightest indication of evolution having resulted from accidental interferences or leaps nor of actual fundamental differences between apes and the early human stages which may justify a complete separation. On the contrary, the more primitive the stages the closer they resemble anthropoids. The truth of this statement can be proven by the dentition of *Sinanthropus pekinensis*.

DESIGNATIONS AND METHODS

For the purpose of a better understanding, I deem it necessary to give an explanation of the various terms, symbols and abbreviations used in this description, together with explanatory notes on the measurements and their application.

The tooth types are given in abbreviations, selecting the first letter of the name. Capital letters stand for permanent teeth and small ones for deciduous. The numerical following the letter designates the order of the tooth within its group. The numerical when placed above the letter defines an upper tooth, while when placed below means a lower tooth; the numerical in line with the letter stands for lower and upper teeth. For instance, m_1 stands for a first lower deciduous molars, M^2 for a second upper permanent molar, M3 for third lower and upper permanent molars. In the case of the canines the numerical is replaced by an apostrophy. With reference to premolars, I prefer the designation of P_1 and P^2 respectively instead of the usual P_3 and P^4, the latter designation presuming adherence of a theory referring to the probable order of premolars in mammals. Teeth of the right and left sides are designated by abbreviations rt and lt respectively. Germs are listed as "g" and adult teeth as "ad".

Designations of cusps of molars and premolars were taken from Osborn's nomenclature without accepting the theoretical presumptions upon which it is based. Thus in the upper jaw the anterior outer cusp is called paracone, the posterior outer cusp metacone, the anterior inner cusp protocone and the posterior inner cusp hypocone. In the lower jaw the terms used are as follows: the most anterior outer cusp is the protoconid, the following outer cusp is the hypoconid, and the last outer or middle cusp is the mesoconid; the anterior inner cusp is the metaconid and the posterior inner cusp the entoconid. The so-called sixth cusp is designated by 6 or tubercle 6. The anterior part of the lower molars and premolars is called trigonid, the posterior part talonid, the corresponding parts of the upper teeth are trigon and talon respectively.

For the sides of the teeth I have used the following designations: for the outer side in all cases, including the incisors, the buccal (b) side; the inner side the lingual (l) one; the side directed frontally the mesial (m) side and that directed backwards the distal side (d). The chewing surface is the occlusal side (o).

In order to avoid misunderstanding, the following terms were used regardless whether it concerned crowns or roots or branches of the roots, namely: the term "height" implies in regard to the crown always the distance between the tip or the cutting edge of the tooth and the lowest boundary of the enamel on the buccal surface. In upper molars it is the distance between the tip of the paracone and that boundary and in lower molars that between the tip of the protoconid and the neck line. In the case of roots "height" expresses the distance between the apex and the neck line; crowns or roots are thus called high or low. The term "length" means the mesio-distal diameter; a crown or a root or a branch of the root may thus be long or short. The definition "breadth" represents the buccolingual diameter; a crown or a root or a branch of the root may therefore be broad or narrow.

Each description of the individual tooth types is followed by a table containing the available measurements of all specimens. The height of the crown of worn teeth and that of immature roots have also been included; however, in such cases the measurement is within brackets. In the same way are noted measurements concerning partly damaged crowns or roots.

In the course of this study it became apparent that it would facilitate the description if special symbols were given to signify the degree of attrition and the state of development of the roots. The degree of attrition may best be expressed by numericals as follows:

0 - germ (g) or just erupted tooth without any trace of attrition (example: figs. 33, 165).
1 - slight attrition of the most projecting parts of the chewing surface (example: figs. 27, 140).
2 - slightly more advanced attrition, especially of the tips of the cusps (example: figs. 1, 139).
3 - still more advanced than in 2 (example: fig. 161).
4 - cusps completely worn off but with their bases preserved (example: fig. 42).
5 - involving the valleys between the cusps to a large extent (example: figs. 28, 147).
6 - the entire chewing surface worn off (example: figs. 2, 98, 120).
7 - the pulp cavity exposed and filled with secondary dentine (example: figs. 60, 142).
8 - the entire crown worn off almost up to the neck (example: figs. 68, 277 P[1]).

These definitions apply especially to premolars and molars but may also be used to a certain extent when dealing with incisors and canines. However, it is self-evident that in some cases it may be difficult to determine the exact degree of attrition especially when the wear of the tooth is not uniform. In such cases two stages of attrition may be combined.

The condition of the root also requires a special definition. Abbreviations used are as follows:

or - germ without root (example: fig. 78).
1r - root in the first stage of development (example: fig. 39).
2r - root developed to one half of its full size (example: fig. 38).
3r - root with widely extended apex (example: figs. 18, 139).
fr - fully developed root.

With respect to measurements the best instrument is a small sliding compass with broadened legs and provided with a vernier. In order to measure the correct greatest length or breadth the crown or the root as a whole is placed between the two legs perpendicular to the respective main axes of the tooth. The precise determination of the height of the crown is more difficult. It goes without saying that this measurement was taken for comparative purposes only when the tooth was completely intact. Because of the difficulty to define the vertical height of crown or root above the plane of the base, I confined myself to the determination of the distance between tip and lowest boundary of the enamel on the buccal side. This distance was measured also in cases in which the root was bent at the tip.

In order to better demonstrate the results derived from comparative measurements of individual tooth specimens, I made use of the graphic method which was applied for the first time in my study on the development of the chin (1934). This particular method has the advantage of revealing differences or similarities at first sight. As an expression for the bulkiness of the tooth which is referred to as the "robustness" in the following pages the product of length and breadth measurements has been used. The values thus obtained, however, are only of comparative nature and do not represent the measurements of a real area. For further explanation see the chapter on the size of the teeth.

MATERIAL

This study is based on 147 *Sinanthropus* teeth from the main deposit (Locality I) of Choukoutien. As mentioned in the preface, with the exception of two teeth described by Zdansky (1926), the entire material was at my disposal. The specimens were recovered at different levels during the course of the excavations from 1927 to 1937 and ranging from Locus A to Locus O. Of the total number of 147 tooth specimens 64 represent isolated teeth not connected with jaw fragments, while the others are within their jaws, thus making an accurate determination possible. In certain cases, it is true, teeth were found in isolated conditions but nevertheless in immediate contact with the pertaining jaws (mandible of Locus K) or with fragments of the jaws or pertaining skulls (upper teeth and upper jaw of Locus L).

All teeth bear human characters and undoubtedly belong to *Sinanthropus pekinensis* the only hominid recovered from the locality in question. In one instance only the germ of an upper incisor formerly erroneously designated as representing an I^2 of *Sinanthropus* Locus A was found on closer examination to be the germ of an I^1 of *Macacus robustus* Young. Special mention of this specimen will be made below. This *Macacus* complete skulls of which have been recovered represents the only other primate derived from Locality I.

A considerable number of the tooth specimens, namely 31, are represented by germs or just erupted teeth and therefore do not show any attrition, while 11 additional specimens exhibit only the first degree of wear. These facts are of the greatest importance since only teeth the chewing surface of which is completely intact permit an accurate recognition of their characteristic features and thereby an incontestable determination of the species in question. In respect to the estimation of the condition I am in perfect agreement with H. Virchow (1920) and other authors. The former states that only those teeth which are completely intact present a sound basis for morphological analyses, that is to say, they must be free not only from strong attrition but even from faint wear.

The correctness of this statement was borne out most strikingly by the Heidelberg mandible. Aichel (1917) came to the conclusion that the molars of the latter jaw revealed a type fundamentally different from the anthropoids, the first representing a pure "cusp-type" and the latter a pure "wrinkle-type". In reality the molars of the Heidelberg mandible are so strongly worn that only the bases of the cusps are preserved and all the wrinkles, if ever present, have become entirely obliterated (fig. 301 *d*).

Another advantage is that most of the teeth equipped with roots show all stages of development. Only in a few instances the roots are completely or partly broken off.

The state of preservation of almost all the tooth specimens is excellent, with the exception of a few which are either broken or otherwise damaged. A certain number show fine cracks without displacement of the individual parts. Not one of the specimens reveals any indication of decay. Where the attrition has advanced to such an extent as to expose parts of the pulp cavity, it is covered by a thick layer of secondary dentine (see below).

Among our collection the complete permanent dentition of both sides is represented. As to the deciduous dentition no upper teeth have been recovered until now. Moreover, it is interesting that only one isolated deciduous tooth has been found.

The most striking general peculiarity of all teeth is their great variation in size. As demonstrated elsewhere (1935) this variation is much more pronounced than in recent man, especially when a small and uniform population living in the same environment and under the same conditions is taken for comparison. My earlier contention that this variation may be due to sex differences has in the meantime received further support by the recovery of two *Sinanthropus* skulls (I and II, Locus L), together with upper teeth. One of these skulls (I) is large and according to its general appearance that of a male individual, while the other (II) one is small and that of a female. With respect to the teeth, those of the large type were derived from the same site as the male skull, and the small ones together with fragments of the upper jaw from the same site as the female (1937 b) skull. Thus it is rather evident that the large type of teeth belongs to male individuals and the small to females. I shall return to this question below.

In the following catalogue the entire material of tooth specimens is listed, arranged according to type, side, sex, age, degree of attrition, site of recovery and relationship among themselves and to other *Sinanthropus* remains. With regard to the latter the reader is referred to my publication on the *Sinanthropus* population (1935) in which I attempted to attribute the various teeth to certain individuals from the respective sites. I wish to remark, however, that some data given in the earlier publication are here corrected in conformation to new findings. The teeth listed are arranged according to their type and to the individuals to which they belong. The determination of sex implies that the tooth belongs to the large (♂) or to the small (♀) type.

CATALOGUE

I. PERMANENT DENTITION

A. Isolated teeth

Current No.	Type	Side	Sex	Age in years	Root	Degree of attrition	Site of recovery	Cat. No.	Individual*	Figure No.	Remarks
1	I^1	lt	F	8-9	3r	1	B	65	B I	4 l,o; 249	
2	I^1	rt	F	8-9	3r	1	B	80	B I	3; 274.	
3	I^1	lt	M	ad.	fr	6	D	41	D II	2 b,l,m,d,o	
4	I^1	lt	M	13-14	3r	2	F	33	F IV	1 b,l,m,d,o	
5	I_1	lt	F	ad.	fr	5	D	40	D I	28 b,l,m,d	
6	I^2	rt	F	6	g;lr	0	F	30	F II	19 l; 250, 251	
7	I^2	rt	M	13-14	3r	1	F	36	F IV	18 b,l,m,d,o	
8	I_2	lt	F	7-8	2r	0	A	57	A I	33 b,l,m,d; 253	
9	I_2	rt	F	7-8	—	0	A	58	A I	—	broken
10	I_2	rt	F	9-10	3r	0	C	49	C I	34 b,l,m,d	
11	I_2	lt	F	ad.	fr	5	D	42	D I	36 b,l,m,d	
12	I_2	rt	F	7-8	2r	0	K	97	K II	37 b,l,m,d	
13	C'	lt	F	8-9	lr	0	C	48	C I	39 b,l,m,d; 256	
14	C'	rt	M	ad.	fr	4	D	38	D II	42 b,l,m,d,o; 255	
15	C'	lt	F	ad.	fr	5	D	39	D I	43 b,l,m,d,o	
16	C'	rt	M	13-14	2r	0	F	32	F IV	38 b,l,m,d,o; 257, 260	
17	C,	lt	M	ad.	fr	7	C	29	C II	60 b,l,m,d,o	
18	C,	lt	F	ad.	fr;br	7	C	52	C IV*	53 b,l,m	*Belongs to II cf. Dental formulae
19	P^1	rt	M	13-14	3r	0	F	35	F IV	64 b,l,m,d,o;260,267,325	
20	P_1	rt	M	8-9	lr	0	C	47	C III	80 b,l,m,d,o; 270, 272	
21	P_1	rt	F	ad.	fr	5	D	44	D I	87 b,l,m,d,o	
22	P_1	lt	F	ad.	fr;br	5	F	31	F III	—	
23	P_1	rt	F	ad.	fr	6	H	13	H II	89 b,l,d	
24	P_1	lt	F	ad.	fr	8	H	15	H I	—	

* cf. Dental formulae—appended hereto.

A. Isolated teeth (cont'd)

Current No.	Type	Side	Sex	Age in years	Root	Degree of attrition	Site of recovery	Cat. No.	Individual	Figure	Remarks
25	P^2	lt	F	7-8	lr;br	0	A	68	A I	77 b,l,m,d,o	
26	P^2	lt	F	8-9	or	0	B	66	B I	——	Damaged
27	P^2	lt	F	6	or	0	F	27	F II	78 b,l,m,d,o	
28	P^2	rt	F	ad.	fr	6	I	88	I I	214 m,o	
29	P_3	rt	M	8-9	or	0	C	46	C III	96 b,l,m,d,o; 271, 273	
30	P_3	rt	F	ad.	fr;br	2	F	37	F III	103 l,d,o	
31	M^1	lt	M	ad.	br	6	C	62	C II	——	only half of the crown is preserved
32	M^1	rt	F	ad.	fr	3	D	28	D I	276	roots partly broken off
33	M^1	lt	M	ad.	fr	5/6	D	50	D II*	109 m,d,o; 110	*belongs to L I both buccal roots broken off
34	M_1	lt	F	7-8	2/3r	2	A	1	A I	144 o	
35	M_1	rt	M	ad.	fr	5	A	56	A III	147 b,m,o	
36	M_1	lt	M	9-10	3r	2	C	45	C III	139 b,l,m,d,o; 294, 311	
37	M_1	rt	M	9-10	3r	2	C	53	C III	138	broken
38	M_1	lt	F	ad.	fr	7	I	87	I I	142 b,l,m,d,o; 311	
39	M^2	rt	F	ad.	fr	6	A	54	A II	——	
40	M^2	lt	F	8-9	or	0	B	67	B I	114 b,l,m,d,o; 278	
41	M^2	lt	F	5-6	or	0	B	79	B IV	113 b,l,m,d; 275	
42	M^2	rt	F	ad.	fr	3	D	51	D I	119 b,l,m,d,o	roots partly broken off
43	M_2	lt	F	8-9	or	0	B	63	B I	166 o	
44	M_2	lt	F	5-6	or	0	B	75	B IV	165 b,l,o; 290	
45	M_2	rt	F	ad.	fr	3	D	43	D I	161 b,l,m,d,o	
46	M^3	rt	F	ad.	fr	2	F	34	F III	130 b,l,m,d,o; 279	
47	M^3	lt	F	6	—	0	F	26	F II	128 o; 281	
48	M^3	rt	F	ad.	fr	3	H	14	H II	129 o; 280	
49	M^3	rt	F	ad.	fr	3	I	89	I I	136 b,l,m,d,o	roots partly broken off
50	M_3	lt	M	ad.	—	5	B	64	B II	176 b,l,m,d,o; 295	roots completely broken off
51	M_3	rt	F	ad.	lr	0	D	61	D I	——	
52	M_3	lt	M	8-9	—	0	F	25	F I	177 b,l,m,d,o; 296	

B. Teeth in connection with jaws or skulls

Current No.	Type	Side	Sex	Age in years	Root	Degree of attrition	Site of recovery	Cat. No.	Individual	Figure	Remarks
53	I^1	lt	F	ad	fr	7	L	99	L II Skull	—	
54	I_1	rt	F	8-9	—	1	B	3	B I mandible	27 1; 252	
55	I_1	lt	F	8-9	—	1	B	3	B I "	27 1; 232	
56	I_1	rt	M	8-9	—	—	B	9	B III "	—	crown broken off
57	I_1	rt	M	11	—	2	B	77	B V "	265,302	possibly female
58	I_1	lt	M	11	—	2	B	77	B V "	26 b; 265,302	possibly female
59	I_1	lt	M	ad	fr	4	G	6	G I "	283; 302	root broken off
60	I^2	lt	F	ad	fr	7	L	99	L II Skull	—	
61	I_2	rt	F	8-9	—	1	B	3	B I mandible	27 1; 252	
62	I_2	lt	F	8-9	—	1	B	3	B I "	27 1; 252	
63	I_2	rt	M	8-9	—	—	B	9	B III "	—	crown broken off
64	I_2	rt	M	11	—	2	B	77	B V "	302	possibly female
65	I_2	lt	M	11	—	2	B	77	B V "	26 b; 265; 266	possibly female
66	I_2	lt	M	ad	fr	6	G	6	G I "	283	root broken off
67	I_2	rt	F	ad	—	7	H	83	H IV "	—	
68	C′	lt	M	ad	fr	4	L	98	L I Skull	62 b; 73 d; 254, 259, 263	root in connection with the jaw
69	C′	lt	F	ad	fr	6	L	99	L II Skull	73 m; 262, 263	"
70	C,	lt	F	8-9	1/2 r	0	B	3	B I mandible	50 b,l,m,d,o; 261	removed by preparation
71	C,	rt	M	11	—	0	B	77	B V "	51 b,l; 265	erupting, possibly female
72	C,	lt	M	11	1/2 r	0	B	77	B V "	52 b,l,d; 265, 266	partly exposed by preparation
73	C,	lt	M	ad	—	4	G	6	G I "	54 b,56 l; 283	
74	C,	rt	F	ad	—	7	H	83	H IV "	—	
75	C,	lt	M	ad	fr	5	K	96	K I "	55 b,l,m,d; 287	
76	P^1	rt	M	ad	fr	7	L	98	L I Skull	—	damaged, not connected
77	P^1	lt	M	ad	fr	7	L	98	L I Skull	65 b,l,d,o; 73 c; 259, 264, 268	not connected
78	P^1	rt	F	ad	fr	8	L	99	L II Skull	68 b,l,m; 73 d; 127; 262; 264; 269	within the jaw
79	P^1	lt	F	ad	fr	8	L	99	L II Skull	277	within the jaw, crown damaged

B. Teeth in connection with jaws or skulls (cont'd)

Current No.	Type	Side	Sex	Age in years	Root	Degree of attrition	Site of recovery	Cat. No.	Individual	Figure	Remarks
80	P_1	rt	F	8-9	lr	0	B	3	B I mandible	79 b,l,m,d,o,372	
81	P_1	rt	M	11	—	0	B	77	B V "	83 b,l,o; 265,266	removed by preparation; possibly female
82	P_1	rt	M	ad	fr	6	G	60	G I "	82 b,l,m,d,o; 91	loose tooth
83	P_1	lt	M	ad	—	6	G	6	G I "	283	
84	P_1	rt	F	ad	—	7	H	83	H IV "	——	damaged
85	P_1	lt	M	ad	fr	6	K	96	K I "	86 b,l,m,d,o; 287	
86	P^2	rt	M	ad	—	7	L	98	L I Skull	——	demaged, not in connection
87	P^2	rt	F	ad	fr	6/7	L	99	L II Skull	75 b,l,m,d	
88	P^2	lt	F	ad	fr	6/7	L	99	L II Skull	127 o; 277	
89	P_2	rt	F	8-9	lr	0	B	3	B I mandible	97 b,l,m,d,o; 273, 274	removed, by preparation
90	P_2	rt	M	11	1/2 r	0	B	77	B V "	101 b,l,m,d,o; 273	possibly female
91	P_2	lt	M	ad	—	6	G	6	G I "	283	
92	P_2	rt	F	ad	—	7	H	83	H IV "	——	
93	P_2	lt	M	ad	fr	6	K	96	K I "	98 b,l,m,d,o;287	
94	M^1	rt	F	ad	fr	7	L	99	L II Skull	313 a	
95	M^1	lt	F	ad	fr	7	L	99	L II Skull	127 o; 277	
96	M_1	rt	F	ad	—	7	A	2	A II mandible	180, 284, 289	
97	M_1	rt	F	8-9	—	3	B	3	B I "	145 o	root broken off
98	M_1	rt	M	8-9	2 r	1	B	9	B III "	140 b,l,m,d,o	
99	M_1	rt	M	8-9	2 r	2/3	F	5	F I "	148 b,l,m	
100	M_1	lt	M	ad	—	7	G	6	G I "	283	
101	M_1	rt	F	ad	—	8	H	83	H IV "	——	
102	M_1	lt	M	ad	fr	7	K	96	K I "	141 b,l,m,d,o; 287	
103	M^2	rt	M	ad	fr	7	L	98	L I Skull	——	possibly M^1, no connection; crown damaged, only b-d root preserved
104	M^2	rt	F	ad	fr	6	L	99	L II Skull	120 b,l,m,d,o; 313 b	
105	M^2	lt	F	ad	fr	6	L	99	L II Skull	127 o; 122 m; 277	

B. Teeth in connection with jaws or skulls (cont'd)

Current No.	Type	Side	Sex	Age in years	Root	Degree of attrition	Site of recovery	Cat. No.	Individual	Figure	Remarks
106	M_2	rt	F	ad	—	6/7	A	2	A II mandible	108, 284, 289	
107	M_2	rt	F	8-9	g	0	C	4	C I "	164 o	
108	M_2	rt	M	8-9	g	0	F	5	F I "	163 o	
109	M_2	rt	M	ad	—	6/7	G	7	G I "	——	damaged
110	M_2	lt	M	ad	—	6	G	6	G I "	283	
111	M_2	lt	M	ad	fr	6	K	96	K I "	287	
112	M^3	rt	F	ad	fr	5	L	99	L II Skull	135 b,l,m,d,o	
113	M^3	lt	F	ad	fr	5	L	99	L II Skull	127 o; 277	
114	M_3	rt	F	ad	fr	5	A	2	A II mandible	172 b,l,m,d, 173 a,b, 180, 284, 289	
115	M_3	rt	M	ad	—	5	G	7	G I "	174	
116	M_3	lt	M	ad	—	5	G	6	G I "	175, 283	
117	M_3	rt	F	ad	—	8	H	12	H I "	——	

II. DECIDUOUS DENTITION

Teeth in connection with jaws

Current No.	Type	Side	Sex	Age in years	Root	Degree of attrition	Site of recovery	Cat. No.	Individual	Figure	Remarks
118	i_1	rt	F	5-6	—	2	B	76	B IV mandible	186 b,l,m,d,o; 299, 303	
119	i_2	rt	F	5-6	—	—	B	76	B IV "	299, 303	crown damaged
120	c_1	rt	F	5-6	—	0	B	76	B IV "	188 b,l,m,d,o; 299, 303	
121	c_1	rt	F	8-9	—	4	B	3	B I "	191, 252	
122	c_1	lt	F	8-9	—	4	B	3	B I "	190 b,l,m,d; 252	
123	m_1	rt	F	8-9	—	5/6	B	3	B I "	199	
124	m_1	rt	M	8-9	—	—	B	9	B III "	341	crown broken off
125	m_1	rt	F	5-6	—	2-3	B	76	B IV "	194 b,l,m,d,o; 299, 303	
126	m_2	rt	F	8-9	—	6	B	3	B I "	199, 211 b	
127	m_2	rt	M	8-9	—	6	B	9	B III "	204	
128	m_2	rt	F	5-6	—	3	B	76	B IV "	202 b,l,m,d,o; 299, 303	
129	m_2	rt	M	11	—	7	B	77	B V "	203	possibly female

During the excavations in the spring of 1937 additional *Sinanthropus* teeth were recovered but too late to be included in the list of material. These teeth are now recorded according to the date of recovery. They receive a temporary number followed by an apostrophy in order to distinguish them from our permanent record.

Current No.	Type	Side	Sex	Age in years	Root	Degree of attrition	Site of recovery	Cat. No.	Individual	Figure	Remarks
130′	P_1	rt	M	ad	fr	3	Level 26	301	M I	328	
131′	M_3	rt	M?	c. 10	2 r	0	" 26	302	L IV	340	
132′	P_1	lt	M	ad	fr	3-4	" 26	303	M I	—	with mandible
133′	P^2	lt	M?	c. 10	br	1	" 25	304	L IV	327	
134′	M_1	lt	M	ad	fr	4	" 26	305	M III	—	
135′	I_1	rt	M?	c. 10	3 r	2	" 26	307	L IV	—	
136′	M_3	lt	M	ad	fr	4	" 26	308	M I	—	
137′	$M_1(M_2)$	lt	M?	c. 10	3 r	1	" 25	309	L IV	339	
138′	M_3	lt	M	ad	fr	4	" 27	310	M III	—	
139′	m_3	lt	F	c. 4-5	1 r	2	" 27	311	N I	343, 344	
140′	M^1	lt	F	c. 4	0	0	" 27	312	N I	330	
141′	I^2	lt	F	ad	fr	7	" 29	313	O I	345	together with the upper jaw
142′	P^1	lt	F	ad	fr	6	" 29	313	O I		
143′	P^2	lt	F	ad	fr	6	" 29	313	O I		
144′	M^1	lt	F	ad	fr	6	" 29	313	O I		
145′	M^2	lt	F	ad	fr	6	" 29	313	O I		
146′	M^3	lt	F	ad	fr	6	" 29	313	O I		
147′	M_1	lt	M	ad	fr	7	" 29	314	O II		

DENTAL FORMULÆ OF THE *SINANTHROPUS* MATERIAL*

Explanation: $\frac{\text{left} \mid \text{right}}{\mid}$ upper teeth
lower teeth

Locus	Individual	Age in years	Sex	Formula
A	I	7-8	F	$\frac{P^2(25)\mid}{M_1(34, Bl);\ P_1(Zd);\ I_2(8)\mid I_2(9)}$
A	II	Adult	F	$\frac{\mid M^2(39)}{\mid M_1(\mathit{96});\ M_2(\mathit{106});\ M_3(\mathit{114})}$
A	III	Adult	M	$\frac{\mid M^3(Zd)}{\mid M_1(35)}$
B	I	8-9	F	$\frac{M^2(40);\ P^2(26);\ I^1(1)\mid I^1(2)}{M_3(43);\ C_1(\mathit{70});\ c_1(\mathit{122});\ I_2(62);\ I_1(55)\mid I_1(\mathit{54});\ \mid I_2(\mathit{61});\ c_1(\mathit{121});\ m_1(\mathit{123});\ m_2(\mathit{126});\ M_1(\mathit{97})}$
B	II	Adult	M	$\frac{P^{1**};\ C^{1**}\mid}{M_3(50)\quad\mid}$
B	III	8-9	M	$\overline{\mid I_1(\mathit{56});\ I_2(\mathit{63});\ c^*;\ m_1(\mathit{124});\ m_2(\mathit{127});\ M_1(\mathit{98})}$
B	IV	5-6	F	$\frac{M^2(41)\mid}{M^2(44)\mid i_1(\mathit{118});\ i_2(\mathit{119});\ c_1(\mathit{120});\ m_1(\mathit{125});\ m_2(\mathit{128})}$
B	V	11	M	$\overline{C_1(\mathit{72});\ I_2(\mathit{65});\ I_1(\mathit{58});\ \mid I_1(\mathit{57});\ I_2(\mathit{64});\ C_1(\mathit{71});\ P_1(\mathit{81});\ m_2(\mathit{129});\ P_2(\mathit{90})}$
C	I	8-9	F	$\frac{C'(13)\mid}{\mid I_2(10);\ M_2(\mathit{107})}$
C	II	Adult	M	$\frac{\mid M^1(31)}{C_1(17)\mid}$
C	III	9-10	M	$\overline{M_1(36)\mid P_1(20);\ P_2(29);\ M_1(36)}$
C	IV	Adult	F	see J I
D	I	Adult	F	$\frac{C'(15)\quad\mid M^1(32);\ M^2(45)}{I_2(11);\ I_1(5)\mid P_1(21);\ M_2(45);\ M_3(51)}$
D	II	8-9	M	see L I
F	I	8-9	M	$\overline{M_3(52)\mid M_1(99);\ M_2(\mathit{108})}$

* Teeth *in situ* or in connection with jaws or skull are in italics.
Numericals within brackets refer to catalogue number.
Abbreviation: Bl = described by Davidson Black, Zd = described by Zdansky.

** Completely broken, not included in the catalogue.

Locus	Individual	Age in years	Sex	Formula
F	II	5-6	M	$\underline{M^3(47); P^2(27) \mid I^2(6)}$
F	III	Adult	F	$\underline{\mid M^3(46)}$ $P_1(22) \mid \overline{P_2(30)}$
F	IV	13-14	M	$\underline{I^1(4) \mid I^2(7); C'(16); P^1(19)}$
G	I	Adult	M	$\overline{M_3(116); M_2(110); M_1(100); P_2(91); P_1(83); C_1(73); I_2(66); I_1(59) \mid P_1(82); M_2(109); M_3(115)}$
H	I	Adult	F	$\overline{P_1(24)} \mid \overline{M_3(117)}$
H	II	Adult	F	$\mid M^3(48)$ $\mid P_1(23)$
H	IV	Adult	F	$\overline{\mid I_2(67); C_1(74); P_1(84); P_2(92); M_1(101)}$
I	I*	Adult	F	$\underline{\mid P^2(28); M^3(49)}$ $\overline{M_1(38); C_1(18)} \mid$
K	I	Adult	M	$\overline{M_2(111); M_1(102); P_2(93); P_1(85); C(75)} \mid$
K	II	7-8	F	$\overline{\mid I_2(12)}$
L	I**	Adult	M	$\underline{M^1(33); C'(68); P^1(77); I^1(3) \mid C'(14); P^1(96); P^2(86); M^2(103)}$
L	II	Adult	F	$\underline{M^3(113); M^2(105); M^1(95); P^2(88); P^1(79); C'(69); I^2(60); I^1(53) \mid P^1(78); P^2(87); M^1(94); M^2(104); M^3(112)}$
L	IV	Adolesc.	M	$P^2(133') \mid$ $\overline{M_{1(2)}(137')} \mid \overline{I_1(135'); M_1(131')}$
M	I	Adolesc.	M	$\overline{M_2(136'); P_1(132')} \mid \overline{P_1(130')}$
M	III	Adult	M	$\overline{M_1(134'); M_2(138')} \mid$
N	I	4-5	F	$\underline{M^1(140')} \mid$ $m_2(139') \mid$
O	I	Adult	F	$\underline{M^3(146'); M^2(145'); M^1(144') \cdot P^2(143'); P^1(142'); I^2(141')} \mid$
O	II	Adult	M	$\overline{M_1(147')} \mid$

* identical with C IV.

** identical with D II.

The recording of the data in the preceding catalogue and lists as well as the diagnosis of the types of isolated teeth was greatly facilitated by the fact that, with the exception of the central upper incisors and the upper canines, all types could be compared with those embedded within the jaws. Thus in exceptional cases only could the order of the molars be stated incorrectly. However, since the third molars, upper and lower, are so characteristic in their appearance, the possibility of mistaking them for first or second molars is very slight. In regard to the identification of first and second molars the degree of attrition is of great aid, especially when dealing with germs. The youngest *Sinanthropus* individual hitherto recovered in whom the first permanent molar has already erupted (B IV) is a child of about 5-6 years. Thus molar germs at hand probably belong to second molars. In attributing isolated teeth to certain individuals and thereby connecting them with other types of teeth found in the same level, the size, degree of development of roots and the degree of attrition serve as decisive factors.

For the purpose of a better understanding as to how these data were derived, it is deemed advisable to give a brief description of the excavations at Locality I. As is described in "Fossil Man in China" (1933), in the field seasons of 1928-1929 excavations were carried out on the north side of the limestone wall downward to the bottom of the so-called "Lower Fissure." *Sinanthropus* material consisting of jaws, skull and isolated teeth were recovered during this period and designated according to the site of recovery as material of Locus D, E and F. Since then the excavations were not confined to such small pit-like areas but extended over the entire area of the cave, starting from the top and gradually proceeding to the bottom. In this way the same levels of those Loci were exposed again but now in much larger horizontal layers. Following Davidson Black's method of designation the sites of recovery of additional *Sinanthropus* material have been called Loci I, K, L, etc. Thus the new level of Locus I corresponds to that of the former Locus C and that of the new Locus L to that of the former Locus D. This being the case, it is quite possible that some of the *Sinanthropus* teeth derived from Locus C and D may be related to material from Locus I and, indeed, the correctness of this assumption seems to be borne out by the upper right canine of Locus D recovered in 1929 which undoubtedly belongs to the dentition of Skull I of Locus L unearthed in 1936 and of which the left upper canine was found. These two canines correspond perfectly in size and shape of their crowns as well as of their roots and in the degree of attrition (compare figs. 42 *d* and 73 *a*).

As is evident from the catalogue the number of each type is as follows:

PERMANENT DENTITION:

Upper teeth: I^1 : 5; I^2 : 4; C' : 6; P^1 : 6; P^2 : 9; M^1 : 7; M^2 : 8; M^3 : 7.
Lower teeth: I_1 : 8; I_2 : 12; $C_,$: 8; P_1 : 13; P_2 : 7; M_1 : 14; M_2 : 10; M_3 : 10.

DECIDUOUS DENTITION:

Upper teeth: None
Lower teeth: i_1 : 1; i_2 : 1; c : 3; m_1 : 3; m_2 : 5.

The total number of upper permanent tooth specimens is thus 52 and of lower 82. The larger number of lower teeth is due to the presence of many isolated lower mandibles the upper jaws or skulls of which are missing.

In the publication on the *Sinanthropus* population (1935) I gave a list of the entire material then at hand arranged according to the sites of recovery and the supposed individuals. The list given here completes the first and includes corrections which had to be made in view of the more exact data available at present. The list shows that we are now dealing with 32 individuals represented entirely or partly by tooth remains; 20 of them are adolescent or adult individuals and 12 children from 4 to 14 years of age. As to the sex, 16 individuals are males and 16 females, namely 6 male children and 10 male adults and 6 female children and 10 female adult individuals. The entire *Sinanthropus* population of Choukoutien represented today is approximately 36. It is possible though that in two cases remains considered as representing a separate individual belong to one already listed. This would reduce the total to 34 individuals.

I. COMPARATIVE DESCRIPTION OF INDIVIDUAL TYPES

A. THE PERMANENT DENTITION

I. INCISOR

a. UPPER INCISORS

The central incisor (figs. 1-4, 247, 249).

The description of the central upper incisor is based on four isolated and well preserved specimens of which only one is worn to a greater extent. Although we have not recovered any upper central incisors embedded in the jaw, yet the form of these teeth and the differences between those of the right and left sides are so apparent that their correct determination was made without difficulty. Two of these incisors may represent the large type and hence pertain to male and two to the small type and hence belong to female individuals.

The central incisor is characteristic by its large, wide and relatively flat crown. The buccal surface is strongly convex in sagittal as well as in transversal direction as seen in figs. 1, *m*, *d*, *o*; 3, *o* and 4, *o*. The lingual surface is considerably deep in the middle due to the sides being not only strongly thickened but also folded around lingualward, especially on the distal side (figs. 247 and 249). Thus the lingual surface gives the impression of having the shape of a shovel (see below). This feature becomes particularly distinct when the tooth is viewed from the occlusal side (figs. 1, 3, 4; *o*). In all specimens at our disposal the crown ends in a slightly curved cutting edge. Whether there had been a crenulated rim as may be supposed cannot be defined on account of the attrition undergone by all of the available incisors. In combination with this shovel-shaped appearance there is another characteristic feature with respect to the basal part. The lateral borders are here united by a strong median eminence, the so-called basal tubercle (tuberculum dentale). This tubercle slopes towards the middle pit of the surface and its free border is divided into several finger-like prolongations which end abruptly after a longer or shorter course (figs. 1, 3, 4; *l*). The union of the two lateral borders with the tubercle does not occur in the same level, the mesial border in most of the cases courses somewhat more towards the base than the distal one. Yet this feature does not present a reliable criterion for the definition of mesial and distal borders and thereby the right and left tooth, because the distal border also may at times continue still further towards the base (compare figs. 3 and 4, *l*). A reliable criterion, however, may be found in the distal border which continues to the cutting edge by a distinctly outward curved line, while the mesial border meets the edge at a straight right angle. This peculiarity is still more pronounced in recent man and represents the so-called "angle-character" (Winkelmerkmal, fig. 5; *b*, *l*). The phenomenon that—in recent man—the mesial part of the buccal surface appears stronger vaulted in the transversal plane than its distal part was noted by Mühlreiter and termed "curvature-character" (Krümmungsmerkmal). As figs. 3, *o* and 4, *o* demonstrate, in *Sinanthropus* the distal part in particular is the more salient one, although this feature may be completely absent (fig. 1, *o*).

The root of the central incisors exhibits an awl-shape. It is thick and round but slightly flattend at the neck part in buccolingual dimeter and gradually tapering toward the tip. The distal side occasionally bears an indication of a very shallow furrow (figs. 1, *d* and 3, *l*). The widened neck part of the root continues directly into the crown without any constriction at the neck with the exception of the buccal and lingual surfaces of the crown which project beyond the neck. The boundary between the crown and the root lies on the buccal and lingual sides in about the same level. Occasionally the former or the latter reaches slightly lower while on the mesial as well as on the distal sides of the tooth it is pushed forward considerably towards the crown.

Mühlreiter called attention to the fact that in recent man the longitudinal axis of the root and that of the crown forms an obtuse angle—"profile angle" after Lenhossek—so that the edge of the crown recedes more or less lingualward (fig. 5, *m*). It is remarkable that such an angle does not exist in *Sinanthropus,* where the axis of the crown courses in the same direction as that of the root (figs. 1, *m*, *d* and 2, *m*, *d*) and where the edge of the crown and the tip of the root are placed in straight line. This feature is of importance in regard to the position occupied by the central incisors in connection with the prognathism of the upper jaw as will be shown below. For the same reason the angle formed between the wear facet and the longitudinal axis of the crown and root is worthy of note. As figs. 1, 2 and 4 demonstrate, this facet forms an acute angle of about 54° with the axis in question.

TABLE I

Measurements of central upper incisors

4: 249 3: 247 2: 1

		No. 1 ♀	No. 2 ♀	No. 3 ♂	No. 4 ♂	No. 53 ♀
crown	height	(10.4)	(8.4)	(9.5)	13.3	(4.3)
	length	9.9	9.8	10.8	10.7	(7.2)
	breadth	7.6	7.9	7.5	8.1	7.5
root	height	—	18.3	18.0	11.5	20.7
	length	7.3	7.6	8.2	8.0	5.1
	breadth	7.0	7.6	6.4	7.1	7.3

5,3

The upper central incisor of *Sinanthropus* when compared with those of recent man (fig. 5) reveals other characteristic differences. Both crown and root are larger; the crown is longer and higher but the breadth is about the same; the neck line is less marked; the root is higher and more robust in all dimensions. As to the lingual surface of recent man there is a distinction between European and Mongol teeth. In the former the lateral borders are not at all or faintly folded lingualward with the lower part of the surface flat or slightly deepened (fig. 5, *l*), while in Mongols (Northern Chinese) these borders are thickened and bent considerably lingualward, so that the surface proper represents a kind of a cup or a real shovel (figs. 11, 13, 248). There is no doubt that the latter appearance is much more like that observed in *Sinanthropus* than in the European type (compare figs. 3, *l*; 4, *l* and 247 and 249 with figs. 5, *l* and 11, 13 and 248 respectively).

Hrdlicka (1920) was the first one to call attention to the fact that the upper incisors of certain representatives of the Mongol race were distinctly shovel-shaped. In an earlier publication (1935) I remarked on the conformity of this type to *Sinanthropus* incisors and the entire question will be treated below. At this moment I only wish to remove the objection raised by Adloff (1936, 1937) who, although quoting Hrdlicka in particular, disclaims the shovel-shaped character of the central incisors of *Sinanthropus* because of the presence of a strongly developed lingual tubercle. I fail to understand how the existence or non-existence of such a tubercle located at the base of the "shovel" has any connection with the special shape of the lingual surface itself. Hrdlicka himself (1920) defines the shovel-shape as "of a peculiar pronounced hollow of the lingual surface of the teeth, bounded laterally or surrounded by a well defined elevated enamel border." This is exactly the same feature as found in the *Sinanthropus* incisor. The special configuration of the basal tubercle affects the surface itself not any more than the way in which a handle is fixed to the shovel. Figures 1, 3, 4 and 247 and 249 demonstrate the shovel shape of the *Sinanthropus* incisors clearly and show that it is a fact and not an interpretation.

In recent man the lingual tubercle projects more or less at its base but its finger-like prolongations toward the deepened lingual surface vary considerably. In many of the cases they are represented by only a fine and short middle ridge as shown in fig. 5, *l*. There may be found, however, a more complicated pattern in other cases approaching closer to that of *Sinanthropus*. de Jonge-Cohen (1926, 1928 in "Mühlreiter") reproduces a whole series of such variations in recent man—his figs. 5, p. 295 (1926) and fig. 5 A-H (1928). This investigator believes that the tubercle as a rule is provided with two unequally long and broad small folds or ridges. In figures 9, 10, 12 and 13 four different patterns are reproduced as they occur in recent man (see below). With regard to the root a comparison of figure 2 (*Sinanthropus*) with figure 5 (recent European) shows that there is no great difference in the general shape, with the exception that the root of recent man is reduced in all its dimensions.

Thus, when comparing the *Sinanthropus* incisor as a whole with that of recent man the most conspicuous difference to be observed apart from that of size is the configuration of the lingual surface, especially that of the lingual tubercle. As to how the actual relation between these contrasting incisor types may have been is revealed by incisors of the Neanderthal group. Gorjanovic-Kramberger (1906) and H. Virchow (1920) supplied good descriptions and reproductions. The incisor of the Ehringsdorf child (fig. 6) for instance appears exactly as may expected of a transitional form between *Sinanthropus* and recent man. With respect to the size of the crown and root as well as its special appearance this incisor really is intermediary. The shovel shape of the lingual surface is not as pronounced as in *Sinanthropus* because of its lateral borders being less bent inward than in the latter. The Ehringsdorf tooth resembles in this respect the European type more closely than the Mongol one (compare figs. 6, 7, 8 with 11; 13) in which the lateral borders are much sharper set off against the lingual surface than is true in the European incisor. On the other hand the basal part of the lingual tubercle is clearly more protruding and the whole tubercle is stronger in the Neanderthal teeth than in the *Sinanthropus* incisors at hand, while the finger-like prolongations are smaller and less numerous. The latter is also true of the central incisor of the Krapina upper jaw E as may be seen from Gorjanovic-Kramberger's Plate III, fig. 2a, where the tubercle forms a prominent swelling and the prolongations consist of only two or three ridges. In the Krapina tooth germ reproduced here in figure 7 there are three ridges but shorter and smaller than in the *Sinanthropus* incisor. The incisor of Le Moustier (fig. 8) shows the same feature as those present in Ehringsdorf and Krapina, namely a well developed tubercle with three ridges. It is of great interest to note that in the palæolithic recent man of the "Upper Cave" of Choukoutien an incisor was found which also resembles in all its features almost completely those of *Sinanthropus* (fig. 9).

There can be no doubt that pronounced lingual tubercles with several finger-like prolongations extending toward shovel-shaped lingual surfaces represent primitive characters of hominid central incisors and that these features undergo a gradual reduction until they are almost completely lost in the course of human evolution. The variation occurring in recent man, examples of which are given in figures 9-13 and also in de Jonge's figure 5 (see above), demonstrates that the original formation may be more or less retained in certain individuals without preference for a special race. This statement is strictly in contrast to Aichel's conception (1917). The latter, on the basis of observations on incisors of the Neanderthal group, disclaims the regressive character of the lingual tubercle and assumes the existence of two different incisor types already present in fossil hominids, namely the one with a complicated cusp and another like that of recent man. As is revealed by *Sinanthropus* such two-fold differentiation does not occur. The *Sinanthropus* incisors prove also that Adloff's (1907b) contention of a special differentiation of the lingual tubercle in the Neanderthal incisors and of its supposed absence in primitive hominids can no longer withstand the real facts. Both H. Virchow (1920) and Gregory (1921) have pointed out that a well developed lingual tubercle with its complicated surface pattern already characterizes the great apes. Although even here there exists a considerable individual variation (H. Virchow, 1920; Remane 1921), the same configuration as in *Sinanthropus* and the Neanderthal group may be found in gorilla, orang and chimpanzee. In all great apes (figs. 14, 15, 17) the lateral borders are folded lingualward so that the lingual surface shows a shovel-shaped appearance. The lingual tubercle occasionally is strongly developed, especially and rather regularly in gorilla in which the greatest part of the surface is occupied by the tubercle and the differentiation of its lower border (fig. 15). In orang (fig. 17) and chimpanzee (fig. 14) the same feature may be observed, though as a rule it is more simple in these apes. Thus, the lingual tubercle in the special form as in *Sinanthropus* is a characteristic feature of the anthropoid incisor. Although it has the tendency to reduce in the course of human evolution together with the general reduction of the size of the whole tooth, yet this regressive process does not follow an identical path for even in recent man occasionally there may be observed a feature more or less similar to that of *Sinanthropus* (figs. 10 and 13). This condition of the entire tubercle-complex has likewise taken place in each individual group of anthropoids. Hence the supposition that we are dealing with a very primitive anthropoid character because of the absence of the complicated tubercle pattern in all the other Catarrhinæ as well as in Platyrrhinæ and Prosimians. Even in Hylobatidæ which approach anthropoids closely in certain details of the teeth the special differentiation of the lingual tubercle of the upper central incisors is either absent or represented by an insignificant prominence in the middle of the upper rim which borders the lingual surface. For an example of the absence of the tubercle and its pattern in fossil macaque the reader is referred to figure 25 which illustrates a left central incisor. On the other hand the very primitive anthropoid character of the tubercle is proven by its occurrence in the central deciduous incisor of chimpanzee (fig. 16). The fact that *Sinanthropus* and other hominids have this tubercle complex in common exclusively with anthropoids and that the tendency to reduce occurs simultaneously in both cases can only be considered as an indication of the hominids falling within the special group of anthropoids and of not having been immediately derived from some unknown lower primate group. We shall return to this problem later.

The lateral incisor (figs. 18, 19, 250, 251, 345).

It is a strange fact that the lateral upper incisor of *Sinanthropus* in our collection is represented only by two isolated immature teeth, a germ (fig. 19) and an erupted tooth but not fully developed (fig. 18), and one tooth *in situ* which is rather worn. According to size the tooth *in situ* and one of the immature teeth pertain to female individuals and the other to a male individual.

In contrast to the central incisor the lateral incisor is a small tooth. This is especially true for the crown when compared with its own high and broad root (fig. 18) on the one hand and with that of the central incisor (figs. 1, 2) on the other. The crown is relatively short in the mesiodistal diameter but broad in the buccolingual one so that it presents a wedge-like shape when viewed from the occlusal side with the edge directed lingualward (fig. 19, *o*). The buccal surface is high and relatively narrow; it is well vaulted in transversal plane—slightly more on its distal side—while it is flatter in sagittal plane. The distal side continues into the cutting edge with a rounded-off corner where the mesial side forms more of a right angle to that edge. Right and left incisors may be distinguished by this difference. The cutting edge itself is represented by a distinctly crenulated rim (fig. 19, *l*); in the case of figure 19 there are two or four dents respectively. The lingual surface exhibits a deep *fovea dentis*, that is to say the thickened borders bulge strongly in lingual direction causing the lingual surface to appear in the form of a cup or a shovel with its deepest part at the base. The borders bear a fine edge which continues into the cutting edge and gradually thickens toward the base, without forming a distinctly separated lingual tubercle (fig. 18 *l*, 19 *l*). A special differentiation may be slightly indicated by fine lines (fig. 19 *l*) or notches in the basal region of the bulging wall.

The root differs considerably from that of the central incisor. In proportion to the crown it is higher and stronger and distinctly flattened in mesiodistal direction. The buccal surface of root and crown shows an equal convexity with that of the crown receding lingualward. Nevertheless, the longitudinal axes of the root and crown form a straight line and do not display any deviation from the crown, neither in lateral nor in sagittal directions. The mesial as well as the distal root surfaces clearly exhibit longitudinal furrows. As in the case of the central incisor, root and crown are not separated by any distinct constriction in the neck part, although the mesial and distal sides of the crown bulge out considerably. The neckline on both of these sides reaches further downward than on the buccal and lingual sides, this sinuosity being more pronounced on the mesial than on the distal side.

TABLE II

Measurements of lateral upper incisors

19:251:250 18

		No. 6 ♀	No. 7 ♂	No. *141'* ♀
crown	height	11.9	11.4	(2.7):
	length	8.3	8.2	(6.0) ω
	breadth	8.2	8.1	8.0
root	height	—	(17.3)	19.0
	length	5.7	6.2	5.6
	breadth	8.0	8.1	7.6

0,5

The lateral upper incisor of *Sinanthropus* when compared with that of recent man (fig. 20) shows a conspicuous difference with respect to the height and robustness of the root. In recent man the root is lower, weaker, more awl-like and slender, especially in the neck part so that the base of the crown is protuberant all around. The crown is less stout in recent man but the size as a whole does not differ considerably. The cutting edge is either plain or bears two or more small dents. As in the case of the central incisor, the lingual surface in recent man shows quite a different aspect from that in *Sinanthropus*. Here again distinction must be made between Mongols and other races. In the latter (figs. 10 and 20, *l*) the surface in question is slightly concave with the surrounding borders elevated to a small extent only, although a lingual tubercle is distinctly developed. In the Mongol group of mankind (figs. 11 and 251) these borders form thick and strongly protruding rims which give the crown the appearance of being shovel-shaped (Hrdlicka, 1920). Here also a lingual tubercle may be seen which however only represents the middle, more or less delimited, basal part of the surrounding borders.

The incisor type of recent man can easily be traced back to *Sinanthropus* since the major differences pertain to the size only, especially when taking it as a basis for comparison with the Mongolian group. The Neanderthal man occupies an intermediary position in this respect also (figs. 21-23). This is especially true for the incisor of the man of Le Moustier (fig. 22) and the one of Krapina illustrated in figure 23. The essential difference from the incisor of recent man is the existence of a fairly well developed lingual tubercle which is divided by a fine notch into two small cusps. The shovel shape is only faintly indicated so that the incisors of the two representatives of the Neanderthal group are much more similar to the European type of recent man (fig. 20, *l*) than to the Mongol (figs. 11 and 251). The incisor of the Ehringsdorf child (fig. 21) is characterized by a deeper *fovea dentis* but mainly by a large and protruding lingual tubercle; such a large tubercle is also present on the incisors of the Krapina maxilla E. The peculiar development of this formation has repeatedly been a topic of discussion (Adloff, 1907b; Aichel, 1917) and considered to be an indication of a special differentiation detached from the direct course of human evolution. It is true, *Sinanthropus* comes closer to recent man in this respect because of the absence of a particularly large or complicated lingual tubercle but this fact does not in the least mean that such a formation had never occurred in *Sinanthropus* or in another similar forerunner of the Neanderthal man. Krapina man serves as an excellent proof for in him all stages of development may be found—from small tubercles like those in figure 23 to larger ones like those in maxilla E and extraordinary large ones like those illustrated by Gorjanovic-Kramberger (1906) in his figure 41 (p. 196). The basal part of the lingual surface varies considerably in recent man also. I wish to point out in particular the description and figures supplied by de Jonge-Cohen (1926, 1928) from which it is evident that every variation from a big osteoma-like tubercle to its complete absence may be found without an indication of preference for special races. The Ordos incisor (fig. 24) pertaining to palæolithic recent man and described by Davidson Black (1927) shows a moderately shovel-shaped lingual surface with the middle basal part of its surrounding border cut by fine fissures to form a separated lingual tubercle.

In anthropoids the appearance of lateral incisors varies not inconsiderably. In gorilla and orang there does not exist a straight cutting edge like that in hominids, the edge being distinctly pointed in the former, whereas the chimpanzee resembles the hominids in this feature (fig. 14). The basal and central parts of the lingual surface of gorilla and orang are, in accordance with the tapering of the edge, more or less convex and deepen toward the lateral borders. In connection with this peculiarity the lingual tubercle is somewhat indistinct and represents only a general swelling of the basal part. The entire surface is concave in the chimpanzee (fig. 14), the surrounding borders forming a narrow and sharp rim while in most of the other cases the tubercle is represented by a mere thickening of the middle part of the basal border which likewise ends in a sharp rim.

The feature of the formation in question is of special interest in monkeys. Our collection of *Sinanthropus* teeth contains an upper incisor derived from Locus A designated as *Sinanthropus* I^2 left (fig. 25). As a matter of fact this tooth is very similar to the *Sinanthropus* tooth illustrated in figure 19, but it differs from it by a very fine rim on the cutting edge and by a peculiar fold along the longitudinal axis of the crown. The riddle of this discrepancy was solved when during the excavation last year a skull of a macaque child was recovered with deciduous upper teeth and germs of two central incisors exposed. These central incisors show exactly the same feature as the supposed lateral *Sinanthropus* incisor of figure 25. Thus, we were concerned with a macaque tooth and not with one of *Sinanthropus*. The most interesting fact, however, is that this central incisor of the macaque has the same appearance as the lateral incisor of *Sinanthropus* if the longitudinal fold of the former were disregarded. Therefore, it stands to reason that the central and lateral incisors of the Catarrhinæ may originally have had a shovel-shaped lingual surface with rather equally thickened and rounded borders and without specially differentiated lingual tubercles. Such a differentiation took place to a greater extent in the central incisor and to a smaller extent in the lateral one of anthropoids. The lateral incisor of *Sinanthropus* only shows the beginning of that differentiation; in the Neanderthal group the tubercle is more developed while recent man occasionally follows *Sinanthropus* and then again the Neanderthal man. This assumption, I realize, contrasts the prevalent interpretation, namely that the variations occurring in recent man in all cases must be of a regressive nature and therefore derived from some corresponding formations which must have been still more developed in the ancestors. However, I arrived at the conclusion that the tubercles on the lingual side of the upper teeth do not follow this rule. Very strongly developed tubercles on the lingual side can be found to exist in lateral incisors and canines and first and second premolars of recent Chinese as well as European which by far exceed those ever observed in fossil hominids. The so-called Carabelli cusp on the lingual side of the upper molars belongs to the same category. I shall return to this question below.

With regard to the feature of the central and lateral upper incisors in anthropoids Hrdlicka (1920) claims, it is true, that "rimmed and hollowed" incisors are not limited to man but may also be found in a great number of the apes. Yet the rim and fossa condition combined, according to him, does not occur in any of the anthropoids. This rim and the typical human fossa may be characteristic only to hominids. As stated above, the formation of a hollow lingual surface bordered by a thick rim is in any case a pithecoid feature which, either alone or combined, may at times be more developed in one or the other of the groups of Catarrhinæ.

The shovel-shaped incisors in recent mankind. Hrdlicka (1920), as has been pointed out above, was first in calling attention to the fact that shovel-shaped incisors were characteristic for certain Mongol groups of present mankind. He observed them in both central and lateral incisors but to a much higher percentage in the latter. According to that author, distinction must be made between the rim and the lingual fossa proper, the former being produced by marginal overgrowth of the enamel and of its subsequent lateral folding over the lingual surface. And then again Hrdlicka speaks of lateral enamel folds, a statement which gives the impression as if we were dealing with a formation of enamel only. A mere glance at worn incisors of both recent man and *Sinanthropus* (figs. 2, *l* and 3, *o*) will show that the entire crown substance is folded inward, not only the enamel but also the dentine. Hrdlicka defined the formation of a lingual rim as keilodonty and that of a lingual fossa koilomorphy which he apparently considers to represent two entirely different phenomena independent from each other. Also in this respect I fail to agree with that author. The appearance of a hollowed lingual surface seems to me to be more or less dependent upon the existence of a folded border. In any case, Hrdlicka (1920) differentiates within the group of shovel-shaped incisors of recent man three different degrees of development. The better developed grades are designated by "s", the less developed by "ss". Teeth with slight but distinct indications are defined by "tr". In Table III the results obtained by Hrdlicka for American Indian, Eskimo, Mongolian and Melanesian skulls are listed.

TABLE III

	No. of unworn teeth examined	MEDIAN INCISORS (in %)				No. of unworn teeth examined	LATERAL INCISORS (in %)			
		s	ss	tr	no s		s	ss	tr	no s
Amerindians	(277)	67	2.4	9.0	2.0	(300)	76	17	6	1
Eskimo	(40)	37.5	47.5	15	—	(37)	57	43	—	—
Mongolian	(24)	62.5	29	8.5	—	(24)	75	25	—	—
Melanesian	(6)	33	33	—	33	(6)	6.7	—	33	—

The frequency of occurrence of shovel-shaped incisors in living individuals is given in Table IV.

TABLE IV

		MEDIAN INCISORS (in %)				LATERAL INCISORS (in %)			
	sex	s	ss	tr	no s	s	ss	tr	no s
Whites:	♂	1.4	7.6	24.5	66.5	1.4	8.8	36.4	50.0
	♀	2.6	5.2	21.8	70.4	1.0	7.4	29.9	59.6
American Negroes:	♂	4.9	7.6	33.0	54.4	4.5	12.8	38.0	42.1
	♀	3.6	8.0	32.6	56.0	3.8	11.1	35.4	47.5
Chinese:	♂	66.2	23.4	1.3	7.8	56.9	24.0	1.5	9.5
	♀	82.7	12.5	1.0	3.8	68.8	13.5	1.0	3.4
Japanese:	♂	77.9	18.0	—	4.0	12.7	20.3	—	4.0

Montelius (1933), although he did not give any further details, reports that he had observed shovel-shaped incisors in a high percentage of all six upper anterior as well as lower anterior teeth in Chinese individuals. He found such upper incisors in 79% and of the remaining 21% the incisors had either been lost or there existed an excessive abrasion or the shovel-shaped tooth was not developed at all. Thus, the real percentage of the frequency of occurrence was certainly much higher than that quoted by him. Nevertheless, Hrdlicka's and Montelius' figures demonstrate that the shovel shape is a normal tooth pattern among the Mongolian groups, whereas it represents a relatively rare feature among the Whites and Negroes. In an earlier publication (1935) I had concluded from those facts that *Sinanthropus*, because of his central and lateral incisors showing the shovel-shaped pattern in a very pronounced degree, must be closer related to the Mongols of today than to any other racial groups. In addition I pointed out that in the European Neanderthal man such teeth are known to be present but due to their absence in present European mankind, it must be concluded that the special pattern was not transmitted to the European races. There are two possibilities which may serve as explanations of this difference between *Sinanthropus* and Mongol on the one hand and Neanderthal man and European on the other. One possibility is that in the latter case the pattern had disappeared in the course of evolution and the other is that Neanderthal man cannot be considered the direct forerunner of the European mankind of today. A renewed study of the problem led me to the following conception. The lateral incisor is of greater importance in this respect than the central on account of its greater consistency in recent man as proven by the results expressed in the percentage of occurrence above. In Krapina this incisor in particular shows a considerable variation with the shovel shape well developed in maxilla E or only faintly indicated as in figure 23. Therefore, it seems a greater possibility that this special pattern disappeared. If the latter should be true, its persistence in Sinanthropus and Mongolians is only all the more conspicuous and certainly supports the concept of a closer relationship between this fossil and certain types of recent mankind.

Adloff recently (1936, 1937) objected to my earlier statements (1935) on this question. He claims (1) that shovel-shaped incisors do not exist in *Sinanthropus* nor in the Neanderthal man and (2) that teeth with this shape are exclusively found in recent man and (3) that they represent a peculiarity of all races. None of these assertions is correct. As already shown above, the existence of typical shovel-shaped central and lateral *Sinanthropus* incisors according to Hrdlicka's definition is not a matter of interpretation but a fact (compare figs. 1-4, 18, 19, 247, 249, 251). The same holds good for the incisors of the Neanderthal group (compare figs. 6, 21, 22). As to the occurrence of these types in recent mankind the essential point is not that they may be found to a certain extent in all races in a minor percentage but that they occur in special races up to almost 100% as for instance in Eskimo, Chinese, at least as far as the lateral incisors are concerned, and that the same percentage must be taken to be characteristic for *Sinanthropus*.

Hence there can not be the slightest doubt as to the existence of a closer relation of this fossil hominid to the Mongols of today than to any of the other recent races. In the presence of this fact all other details are of secondary importance.

b. LOWER INCISORS

The central incisor (figs. 26-28 and 252)

Of central incisors we have two isolated left teeth and six embedded within their respective jaw fragments. Three of the latter are right and three are left specimens. As to their sex, five may represent the large type (♂) and three the small (♀), the differences in size, however, are not very pronounced.

The crown is small, especially when compared with that of the lateral incisors (fig. 27). The buccal surface is smooth and fairly curved in sagittal as well as in transversal direction (fig. 28), while the cervical parts shows a slightly more prominent transversal band. The lingual surface is slightly concave with the lateral borders folded inward to a slight extent (figs. 26, 27). The cutting edge in all cases is worn, thus rendering a definition of the original appearance impossible. It may be assumed, however, that it was crenellated like the upper and the lateral lower incisors (fig. 33). It is somewhat surprising that a lingual tubercle in its proper form does not actually exist. Instead there is only a faint smooth swelling which is more marked in one case (fig. 28 *l-d*) than in the other (fig. 27). This swelling gradually disappears toward the concavity of the lingual surface.

The root is awl-like and well developed in its buccolingual diameter and compressed in mesiodistal direction (fig. 28). Its neck part is thick and slightly constricted when compared with the cervical part of the crown. On the buccal and lingual surfaces the enamel overhangs considerably more than on the mesial and distal sides with the result that a large sinuosity is present here, especially on the mesial side. The longitudinal axes of the root and crown form a straight line, with the base of the wedge-like crown projecting in buccal and lingual directions to an equal degree.

TABLE V

Measurements of central lower incisors

28 27:252 2'1 265:(1)202/26:265 283:285

		No. 5 ♀	No. 54 ♀	No. 55 ♀	No. 57 ♂	No. 58 ♂	9 307 No 59 ♂	No. 135′ ♂
crown	height	(6.9)	(7.8)	(7.8)	(8.1)	(9.1)	(6.8)	(9.0)
	length	6.0	6.8	6.2	6.7	6.3	6.2	6.7
	breadth	6.4	6.5	6.1	6.2	6.7	6.8	5.8
root	height	(17.2)	(16.8)	(16.8)	18.0	18.0	—	(14.2)
	length	3.9	—	—	3.9	—	—	4.0
	breadth	5.8	—	—	5.8	—	—	5.8

The differences between the lower central incisor of *Sinanthropus* and that of recent man are much less important than those between the upper ones. As demonstrated by a comparison of figures 26-28 and 32 the *Sinanthropus* crown is stouter and reveals greater details in mesial and distal views than the same tooth of recent man. Although the lingual tubercle of the *Sinanthropus* incisor is very poor, this feature is even less developed in recent man. The root is bulkier in all dimensions in *Sinanthropus.*

The Neanderthal man does not show any appreciable difference in crown pattern from that of *Sinanthropus.* The only difference worth noting is the lingual tubercle which in certain cases is somewhat more developed than in the latter (figs. 29 and 30).

In all anthropoids the general shape of the central incisor is the same as in *Sinanthropus.* Differences when present concern the behavior of the lingual tubercle. This formation is represented by a low and heel-like lingual prolongation of the basal part including the cingulum in the great apes. An almost indistinct swelling rises from this heel proceeding upwards to the lingual surface, only to gradually disappear there. In orang, however, it becomes more distinct and may reach, in the form of a cone-like ridge, the cutting edge (fig. 31).

The lateral incisor (figs. 26, 27, 33, 34, 36, 37, 252, 253)

Of the latter type we have five isolated teeth and seven *in situ.* Four of the first group are immature and free from attrition. Seven teeth pertain to the right side and five to the left. Eight teeth represent the small (female) type and four the large (male) type.

In its general appearance the lateral incisor is rather similar to the central incisor, with the exception that it is larger both in respect to crown and root. Some interesting differences, however, may be observed in certain details. Apart from the size the crown is broader, especially in the region of the edge and more curved in sagittal and transversal directions than in the central incisor. The lateral borders are somewhat thickened and slightly folded lingualward, especially near the cutting edge, so that the lingual surface gives the impression of being faintly shovel-shaped (figs. 27, 33 *l*, 34 *l*, 37 *l*). The cutting edge, where free from attrition, shows a very distinct crenulation consisting of four single dents of which the lateral ones are broadest. These crenulations are also to be observed on the buccal and lingual surfaces themselves where they may be seen to course as fine parallel furrows more or less in basal direction. The mesial and distal corners of the cutting edge differ distinctly, the former forming a sharper right angle whereas the latter shows a somewhat more rounded angle, thus the distinction between right and left is easily made. The lingual tubercle in the lateral incisor is similar in feature to that of the central incisor by representing a smooth and even but not too salient prominence at the basal part of the lingual surface, with the result that the enamel of the crown extends more towards the root here than on the buccal side. On the mesial and distal sides there are large sinuosities in the region of the neckline. The tubercle continues toward the edge in a fine and gradually disappearing tip.

The root is relatively bulky, long (fig. 36) and compressed in mesiodistal direction, with the apical half of both mesial and distal surfaces displaying a rather deep longitudinal middle furrow (fig. 34 *m*). The whole root is like a saber bent lingualward with the result that the crown and root together form a more or less pronounced curvature. I shall return to this appearance below. As is true of all other incisor types, the crown appears to be resting on the root, not so much as a special structure but more like a differentiated part of the root itself (fig. 34 *m, d*). This feature is caused by the absence of any constriction of the neck region, a condition quite distinct in some cases.

TABLE VI

Measurements of lateral lower incisors

		33:253	34	36	37	283:285		27:252	26	265:266	283:285
		No. 8	No. 10	No. 11	No. 12	9:307 No. 59	No. 60	No. 62	No. 63	4:302 No. 64	2:302 No. 66
crown	height	10.2	10.7	(6.7)	10.2	(9.8)	(8.4)	(10.7)	(9.5)	(7.2)	(4.1)
	length	7.2	7.2	6.4	6.3	6.8	7.0	7.0	6.8	7.0	—
	breadth	7.1	7.1	6.8	6.4	6.7	7.1	7.0	7.0	7.3	7.3
root	height	(11.2)	(12.4)	18.0	(5.8)	(17.2)	(17.2)	19.0	19.0	—	19.4
	length	5.6	4.3	4.4	3.7	—	—	—	—	5.3	5.2
	breadth	6.9	7.1	6.5	6.0	—	—	—	—	7.2	7.1

The differences between the lateral incisor of *Sinanthropus* and that of recent man (fig. 35) involves the same features as in the cental incisor, the entire tooth, especially the root, being much more robust in the former than in the latter. The buccal surface of the *Sinanthropus* tooth is much more curved in sagittal and transversal directions than that of recent man. The lingual surface of the former has a more distinct relief and is more concave (slightly shovel-shaped) than that of the latter. The lateral incisor of the Neanderthal group (figs. 29 and 30) closely resembles the same tooth of *Sinanthropus*, at least with regard to its general appearance, namely it shows approximately the same convexities of the crown, the folding of the lateral borders and the tendency toward a slight shovel-shaped formation of the lingual surface. Only the lingual tubercle is more pronounced in the Neanderthal tooth than in

Sinanthropus and accordingly continues toward the cutting edge by a single tapering finger-like protuberance (fig. 29), a condition which is only faintly indicated in the case of *Sinanthropus* (fig. 33, *l*).

Comparing the lateral incisor of *Sinanthropus* and that of anthropoids (fig. 31) there does not seem to exist such a great difference between the two types, with the exception that the lateral corner of the edge appears to be cut off and more rounded and the lingual tubercle to be lower and to project heel-like further in posterior direction in anthropoids. In some cases, as for instance in the orang (fig. 31), the crenulations of the cutting edge and the configuration of the lingual surface come very near to the structure in *Sinanthropus*, although these features are distinctly more pronounced in the former.

The upper and lower incisors of *Sinanthropus* considered as a whole reveal all the structures characterizing the incisors of anthropoids. The differences involve only certain details such as the configuration of the lingual tubercle and the differentiations combined therewith. Although these differences may not be more pronounced than those existing between the three genera of apes, yet on account of their special appearance they have to be considered as hominid characteristics.

As is evident from a comparison of *Sinanthropus*, Neanderthal and recent man, all the peculiarities pertaining to the *Sinanthropus* incisors have gradually disappeared in the course of human evolution. There is not only a striking decrease in size and robustness of both crown and root but also a simplification, that is to say they lost more and more in the course of time their distinct pattern until it became just a plain and polished structure. The special features of the lingual tubercle in the various types of upper and lower incisors have been described above. Different viewpoints are held with regard to its significance and its differentiation. Aichel (1917) states that its development depends upon variations of the growth tendency of the tissues forming the tooth germ. Such a truism, however, does not mean much. In addition Aichel considers the lingual tubercle of the Neanderthal incisors, in accordance with Adloff (1907b), as a special differentiation proving that this hominid had already left the direct line of human evolution. Adloff's and Aichel's presupposition along these lines however lack substantial foundation as demonstrated by *Sinanthropus*. Moreover, according to Bolk's (1913 and 1914) "dimere-theory" every mammalian tooth should be composed of two parts, a buccal protomer and lingual deuteromer, each of which should show one originally higher middle point and two lower ones situated on each side, and thus represent the genuine tridentated reptilian tooth. For this reason Bolk considers the tubercle as the "deuteromer" and its three finger-like prolongations on the lingual surface (observable in certain cases pertaining to recent man, cf. above) as remnants of those primary points. He likewise takes the crenulation of the cutting edge as an indication of the same original formation of the "protomer." de Jonge-Cohen (1926) interpreted the manifold variations of the tubercle and crenulation occurring in recent man similar to Bolk. Adloff (1926), however, already pointed out that the variations of both structures are very great. This being the case it is impossible to choose at random just one of them and consider it as representing the original formation. Indeed, incisors of *Sinanthropus* show very distinctly that the lingual tubercle here does not continue in three uneven points as implied by the theory on a more primitive stage of evolution and the same is true for the crenulations of the edge. On the contrary, in *Sinanthropus* more than three points are usually found in complete accord with the appearance of these formations in anthropoids. Furthermore, since recent man can never serve as an example with respect to primitive characters of the dentition on account of its apparently secondary simplification, evidence proving the correctness of Bolk's dimer-theory cannot be produced by referring to such accidental variations in recent man.

A comparative study of the lingual tubercle of the incisors of primates shows that it neither represents a "deuteromer" in Bolk's sense nor a special lingual cusp like that which occurs in premolars and molars. I consider the tubercles as buttresses which developed upon the lingual base of the crown for the purpose of strengthening the tooth against the pressure or force operating in buccolingual direction. Similar formations can be observed already on teeth of fishes. Whether the tubercles constitute direct upgrowths of the cingulum or are merely reinforced by it is, I believe, a matter of less importance.

The special pattern of the tubercle, that is to say, its division into several ridges of varying number, the ribbed feature of the lingual and buccal surfaces more or less pronounced in many cases, and in conjunction with this the crenulations of the cutting edge—all these features quite common to the incisors of anthropoids—must be taken to be a characteristic indication of the existence of a tendency toward complicating the surfaces of the crown, especially the lingual one, by formations of ridges and wrinkles coursing from the edge to the base. This tendency peculiar to anthropoids and hominids is most pronounced in premolars and molars. I shall treat the latter in detail below. With regard to the variation in size of the lingual tubercle observed in particular among the Neanderthal incisors the reader is referred to the description given above.

Many authors laid special stress on the curvature of the incisors, more particularly on that of the central incisors in sagittal direction. H. Virchow (1920) termed this feature as "kyrtodonty" and defined it as a condition of curved teeth with roots inclined inward and the crowns placed vertically. Taking this verbally, it would mean that the teeth form an obtuse angle between crown and root. Such an angle does not exist in *Sinanthropus* (figs. 1 *m*, *d*; 2 *m*, *d*; 28 *m*, *d*); here the axes of crowns and roots represent a completely straight line and only the buccal surfaces of the two parts are more or less curved buccalward. Since the entire problem is in close connection with the manner of implantation of the incisors within the alveolar process, it will be treated in a later section dealing with the dentition of *Sinanthropus* as a whole.

It is conspicuous that the special differentiation of the lingual tubercle characterizing *Sinanthropus* and the other hominids is much more pronounced in the upper central incisors than in the upper lateral ones and only faintly in the lower incisors. Apart from the differences in size and robustness, the latter really resemble those of recent man much more than is true of the corresponding incisors of the Neanderthal group. The reason for the variability in the formation of the tubercle has been explained above, nevertheless the fact that primitive *Sinanthropus* approaches recent man closer in this respect than the more advanced Neanderthal man deserves special note. This also will be discussed below in connection with similar phenomena.

2. CANINES

Although molars, especially the lower ones, are regarded as the most characteristic teeth in classifying a given species, yet in the case of hominids canines have always attracted the greatest attention. The reason for this special interest is evident. If man really descended from an anthropoid stock, it may only be expected that the canines still exhibit some of the peculiarities belonging to that group of apes. These peculiarities will be found all the more pronounced the more primitive the general appearance of the hominid type. When the Heidelberg mandible was unearthed, one of the greatest surprises was that this fossil, although considered to be the most ancient hominid relic in geological and morphological respects, possessed a canine which failed to differ from that of recent man in size, shape or pattern. Therefore, the canine features of *Sinanthropus* are of considerable importance to the problem of human evolution.

All investigators agree to the statement that in recent man there are no great differences to be found in the general appearance of the upper and lower canines and those which do exist only concern the rather insignificant details.

One of the most striking facts revealed by *Sinanthropus*, however, is that there are very distinct dissimilarities between the two types of canines and that they do not involve the size only but also the entire shape and configuration of the crown and its pattern.

a. UPPER CANINE (figs. 38, 39, 42, 43, 254-257, 259-262)

Of the upper dentition we have six canines at hand all of which are composed of isolated teeth but two of them were found together with the skulls. Three canines represent the large (♂) type and three the small (♀) one. The identification of upper canines is not difficult to make, even if they should be strongly worn, because of certain features peculiar to these teeth.

The canine is characterised by great size and robustness of both crown and root so that it represents by far the largest tooth of the entire dentition of *Sinanthropus*. The crown when viewed from the mesial or distal sides (figs. 38; 39 *m, d*; 256, *p*; 257, *m, d*) looks like a wedge, the edge being rather sharply defined and the buccal and lingual surfaces as a whole formed by strongly convex prominences. The base of the crown is surrounded on all sides by a relatively broad and salient band which is distinctly set off from the buccal (39 *b*) and lingual (39 *l*) surfaces. On both mesial and distal sides this band descends to the edge to form a triangular prominence the base of which is rather depressed (figs. 38, 39, 42 *m, d* and 255 *m, d*, 256 *p*, 257). The apex of this triangle continues into the edge and extends slightly further downward on the mesial than on the distal side (figs. 38 *l* and 39 *l*). The existence of a band and the marginal triangular prominences are of extraordinary significance as these formations represent a well developed cingulum. From this basic enclosure the tooth proper arises. Its buccal surface is strongly convex in transversal direction and slightly ribbed (figs. 38; 42; 43, *o*). From the triangular prominences it is delimited occasionally on both sides by a very distinct furrow (fig. 39 *b*, distal side). In certain cases the middle part is elevated to form a broad tapering ridge which ends into the tip (fig. 42, *b*). The lingual surface shows a more complicated pattern (figs. 38 and 39, *l*). The cingulum continues into the middle part by a basal tubercle moderately developed. The tubercle gradually decreases toward the tip of the tooth. On both sides it may be seen that the cingulum or better the marginal triangular prominences project considerably and that they are separated from the lingual surface proper by deep furrows (figs. 38 and 39, *l*). The surface itself exhibits a median broad and blunt ridge which is irregular in width and ends with a small knob-like and rather circumscribed swelling just immediately within the access of the tip. Between this median ridge and the above mentioned marginal furrows there is on the distal side a short irregular accessory ridge. Occasionally the lingual feature is found to be different (figs. 42 and 43, *l*), namely the lingual tubercle is more developed and terminates in several small prolongations like those described in the central upper incisors (compare figs. 42, *l* and fig. 3), while the surface itself is covered by several more or less distinctly prominent ridges (fig. 42, *l*). The cutting edge of the canine tapers into a more or less pointed tip, the distal border of the edge being slightly more curved than the mesial one.

The root of the canine is conspicuous by its height and robustness. It is particularly well developed in the buccolingual diameter (figs. 42 and 43, *m, d*) with its greatest breadth below the middle. Toward the apex the root is rather abruptly constricted, the apex itself being rounded and curved lingual-distalward. Both mesial and distal sides show shallow and narrow furrows coursing along the middle part of the root; the mesial side is flat, the distal convex. As in the case of the incisors there is no distinct constriction in the region of the neck of the tooth, but instead the root merges with the crown and forms a prominent border only with the cingulum. On account of this feature the crown appears to represent merely a point of termination of the root which thickens towards the upper part (fig. 38, *d*). There is not the slightest trace of an angle between the longitudinal axis of crown and root, with the exception of the apex which bends as already mentioned above. The rim of the enamel projects less upward on the mesial and distal sides than on the buccal and lingual, and extends further upward on the buccal than on the lingual side.

TABLE VII

Measurements of upper canines

		39:256 No. 13 ♀	72:255 No. 14 ♂	43 No. 15 ♀	38:257:260 No. 16 ♂	No. 67 ♂	254:259 73:263 No. 68 ♀
crown	height	13.6	(12.0)	(9.8)	14.2	(11.3)	(7.9)
	length	9.3	9.6	9.1	10.5	9.6	8.5 :7.4
	breadth	9.9	10.6	9.8	10.4	10.4	9.8
root	height	—	23.2	21.8	—	22.8	22.4
	length	7.4	7.8	7.2	9.3	8.4	7.7
	breadth	9.5	10.7	8.9	10.5	11.1	9.2

The difference in size is very notable in this canine. There seems to exist a large and a small type which are not linked by intermediate forms. Such contrasting types are illustrated in figures 38 and 39, and 256 *p* and 257 *p*, respectively. My earlier contention (1935) of these large types as belonging to male and the small types to female individuals has been confirmed by the recovery of the two skull of Locus L (1937b) in connection with which we found large upper canines and premolars pertaining to the large and apparently male Skull I and small upper canines and premolars belonging to the small and probably female Skull II (figs. 73, *a*, *b* and 263).

Compared with the upper canine of recent man (fig. 44) the *Sinanthropus* specimen as a whole is not only very much longer and more robust but it also shows striking differences in its proportions of both crown and root. In recent man the crown is high and narrow (fig. 44, *b*, *l*) whereas in *Sinanthropus* it is relatively low and broad, thus giving the tooth a rather stout and firm appearance. The same holds good for the root where the slightly stake-like character evident in recent man is replaced by a large and robust structure. Not less important than these general differences are those concerning the details of the crown. The cingulum and the marginal triangular prominences are completely absent; the two sides of the lingual surface which is bordered by very faint and blunt swellings present merely traces of the originally so well developed features (fig. 44, *l*). The buccal surface is relatively flat and the lingual surface has lost its entire characteristic pattern, with only the basal tubercle and the median ridge slightly indicated. The cutting edge is crowned by a point which appears somewhat in the form of a superposed tip.

Of the Neanderthal man two unworn canines suitable for comparison are at our disposal. The canine of Le Moustier (fig. 40) does not exhibit any of those details characteristic to the *Sinanthropus* canine. The lingual tubercle, however, is strongly developed and forms a special body delimited from the lateral borders by deep and narrow folds on each side. The canine of Krapina (fig. 41) described and illustrated by Gorjanovic-Kramberger (1906) also fails to reveal any of the features characterizing the *Sinanthropus* specimen, with the exception of a faintly indicated pattern on the lingual surface resembling some of the corresponding structures in *Sinanthropus*, as for instance the lingual borders of the triangular prominences and the median ridge. The crown of the two Neanderthal canines is much smaller in size than even the smallest type of *Sinanthropus* (compare figs. 39, 40, 41) and the same is true for the root. Indeed, there is nothing else that demonstrates more distinctly the existent differences between *Sinanthropus* and the Neanderthal representatives than a comparison of their upper canines which at the same time makes evident that the former is much more primitive than the latter.

The canine illustrated in figure 44 was taken to represent a characteristic type for recent man because of its frequent occurrence, especially among white races. *In reality*, however, there exists an astonishingly great variability in recent man when different races come under observation (compare Remane, 1931). Figure 45 illustrates an unworn canine of an Australian Aboriginal which, although large, is distinctly smaller than the *Sinanthropus* type and one in which the cingulum is completely absent on the buccal surface. The lingual surface, however, reveals in contrast to the "European" canine in figure 44 *l* a special pattern showing the major peculiarities of the *Sinanthropus* tooth structure, even though in a much more simplified form (compare fig. 45 and figs. 38; 39; 42; 43, *l*). In our skull material of modern Chinese a considerable number of variations have been observed some of which are given in figures 46-49. All exhibit modifications of the lingual surface involving in the first place the configuration of the cingulum and the basal tubercle: in figures 46 and 48 it may be seen that the latter has developed to a large and separated body resembling quite closely the canine of Le Moustier (fig. 40) in this respect. An interesting feature is also found in the canine illustrated in figure 49. It imitates, so to say, the shovel shape of the lateral incisor so that there do not exist any essential differences between these teeth, with the exception that the basal tubercle is more distinct in the canine. I shall return to this phenomenon later.

All these variations prove that the upper canine of recent man as represented in the majority of cases is to be considered a tooth which has already undergone an extremely strong reduction in size as well as in all essential features. Its variations which seem to occur more frequently in certain races than in others reflect very impressively the course of the reduction but at the same time reveal some apparently progressive tendencies, as for instance the adaptation to the incisor type in recent Chinese. The tendency toward a stronger development of the lingual tubercle is common to both the canine and incisors of recent and Neanderthal man, as already stated above.

It deserves special note that the canines of the Neanderthal group—as far as the specimens available are involved—do not differ to a great extent from certain variations with primitive characters of recent man (compare fig. 40 with figs. 46, 48 and fig. 41 with figs. 45, 47), whereas the differences between the Neanderthal group and *Sinanthropus* are very distinct.

When comparing the upper canine of recent man with that of recent anthropoids no close similarities seem to exist at first sight. The canine of the Neanderthal man does not differ any more in this respect from that of recent man. Such dissimilarities as these have led many authors like Adloff and Bolk to contend the view that direct relations exist between man and great apes. Now that the canines of *Sinanthropus* are available and represent a much more primitive type than the Neanderthal group, the entire problem is given a different aspect. It is true, a merely superficial inspection of the canines in question will fail to show any striking conformities because of the great contrast in size, but careful observations will reveal that existing differences in reality only compose of quantity, so to say, and not of quality. It is most regrettable that the literature is so poor in good illustrations demonstrating the extraordinary variability of canines of living anthropoids, with the exception of Remane (1927) who has published some excellent sketches of canines which differ from the pattern usually attributed to them. One of these is given here in figure 246, a tooth specimen of a female chimpanzee. This canine is not only small and low but also shows that the ratio of height to length and breadth is much less expressed than in the case of the extremely elongated teeth of male individuals, especially in gorilla. The most peculiar structure of the tooth, however, is that the cingulum and triangular prominences reveal exactly the same feature characterizing *Sinanthropus* (compare fig. 246, *l* and *m* with fig. 39, *l* and *m*). The only major difference to be observed concerns the cingular band of the buccal surface and certain details of the configuration of the lingual surface. As to the former, however, it must be kept in mind that the buccal cingulum is at times to be found as a well developed structure in anthropoids also, especially in the orang. With respect to the latter, in apes it forms a further projecting and sharper inclined edge which is somewhat shifted toward the mesial side, whereas in *Sinanthropus* the median ridge is broad and indistinct. I am glad to be in a position of giving drawings (fig. 61) and photographs (fig. 258) of a canine of a fossil orang found in a cave known as Hoshangtung (Province of Yünnan—Southwestern China) and first described and tentatively referred to *Ailurupus* by

C. C. Young. In the meantime many additional teeth (premolars and molars) undoubtedly belonging to orang have been recovered from the same locality and from caves in Kwangsi the associated fauna of which is known to bear the same character as that of Choukoutien.

It is not easy to determine whether this orang canine belongs to the upper or lower dentition. Compared with female canines of recent orang or with chimpanzee, taking all details into consideration, it seems to be an upper tooth (compare figs. 246 and 258), but on the other hand, it is relatively small and low and its length is considerably less than its breadth (11.0: 14.2; index 129.2) with the result that I am inclined to define it as representing a lower canine of a female individual. In any case this specific question is not of such great importance when considering the general character of the tooth, for it completely corresponds to the above described chimpanzee tooth sketched by Remane, with the exception that it is stouter and less sharply tapered. In contrast to the chimpanzee specimen, however, its cingulum is strongly developed on the buccal side also (fig. 61, *d*) and the marginal triangular prominences (*m*, *d*) are marked and rise to a higher level than in the chimpanzee. All these features are in complete conformity with those characterizing the *Sinanthropus* upper canine (figs. 38 and 39 *m*, *d*). Thus every unbiassed student will agree that this orang canine approaches very closely to that of *Sinanthropus*, the differences between them being not greater than those of other corresponding teeth.

b. LOWER CANINE (figs. 50-56, 60, 62, 261, 265, 266, 283, 285, 287, 288)

Eight lower canines are on hand two of which represent isolated specimens while the remaining seven are *in situ*. As already pointed out above, the identification of this tooth type and its distinction from the upper canine is not too difficult. Five canines represent the large type (♂) and three the small one (♀).

The lower canine is a very large tooth and exceeds in size and robustness the adjacent dentition both on the mesial (fig. 285) and distal (fig. 54) sides. Similar to the upper canine the crown shows in mesial (fig. 50 *m*) or distal view (figs. 50 *d*, 52 *d*, 266) a wedge-like feature with a sharp cutting edge, with the buccal surface strongly convex in both sagittal and transversal directions (fig. 50 *m*, *d* and *o*) and the lingual surface (figs. 50 *m*, 52 *d*) slightly concave. Like the upper canine the base of the crown is surrounded on all sides by a distinctly projecting band which is very strongly developed in some cases (figs. 52 *d*; 53 *b*, *l*; 55 *b*). On the mesial and distal sides this band forms triangular prominences with deep depressions within the center of their bases (figs. 50 *m*, *d*). The apex continues into the cutting edge and clearly rises higher on the mesial than on the distal side (fig. 50 *m*, *d*). These marginal prominences are separated from the buccal surface by fine relatively deep furrows which are in all cases more pronounced on the distal than on the mesial side (figs. 50; 53; 54; 55, *d*; 266). There is not the slightest doubt that we are dealing here also with a surprisingly well formed cingulum. The buccal surface itself is slightly ribbed in longitudinal and in transversal directions (figs. 50-55). The lingual surface is characterised by a broad and projecting rim shows three characteristic features. Firstly, its distal of the surface to be deepened with only the median part elevated more or less ridge-like (figs. 50, *l*; 51, *l*; 52, *l*; 56, *l*; 261). This rim is in direct connection with the basal tubercle thus giving the latter the appearance of being an indistinct swelling of the basal part of the rim. The rim shows three characteristic features. Firstly, its distal section is striated by showing fine wrinkles alternating with impression on the deepened part of the surface. Secondly, the median section shows a small circumscribed knob-like protuberance corresponding to the tip of the cutting edge. Thirdly, a very fine brim is placed upon the distal and median section of the rim itself thus forming the cutting edge proper. All these peculiarities are only recognizable in perfect specimens (figs. 50, *l*; 51, *l*; 52, *l*; 261). The cutting edge is furthermore remarkable by its special shape. It does not taper as a whole to the tip but instead courses horizontally, except its middle which is marked by a small pointed elevation continuing downward into the more or less distinct median ridges of the buccal and lingual surfaces (figs. 52; 265, *a*, *b*). Furthermore, the canine is characterized by a slight inflection of the entire crown distinctly toward the distal side (figs. 53, *l*; 54; 56). Corresponding to this particularity the ridges and furrows of the lingual surfaces run in the same distal direction (figs. 50, *l*; 53, *l*; 56). All these features combined give the lower canine of *Sinanthropus* the appearance of being an incisor rather than a canine.

The root of the lower canine resembles very closely that of the upper one (compare figs. 53; 55; 60 with figs. 42; 43). It is high and robust and particularly well developed in bucco-lingual direction. The greatest breadth which exceeds that of the crown is found in the upper third of the root. The root is somewhat abruptly tapering off toward the apex, the latter being bent distinctly lingualward and at the same time either mesially or distally. The mesial and distal surfaces of the root show longitudinal furrows like those of the upper canine (figs. 53; 55; 60), this furrow being clearly deeper impressed on the mesial than on the distal surface. As in the case of the upper canine, there is no constriction at the boundary between crown and root, the separated contours being merly indicated by the projection of the cingulum. The so caused stoutness of the tooth is very evident in figures 53, 54, 60. Occasionlly the boundary of the enamel reaches higher upward on the mesial than on the distal surface. With the exception of the slightly distal inflection of the crown as mentioned above, a distinct deviation of the longitudinal axes of crown and root is not recognizable, the tooth as a whole is faintly curved with a buccal convexity. This curvature, however, never reaches a remarkable degree.

TABLE VIII

Measurements of lower canines

60 53 262: 73 50:26 | 51: 265 | 52:265:266 | 54:56:283

		No. 17 ♂	No. 18 ♀	263 No. 69 ♀	No. 70 ♂	61:352 No. 71 ♂	61:352 No. 72 ♂	285 No. 73 ♀ 4 307 G-1	No. 74 ♂
crown	height	(5.6)	(6.3)	11.7	11.7	11.3	(10.5)	(4.9)	(9.2)
	length	9.0	8.5	8.1	8.4	—	9.0	8.1	8.9
	breadth	10.4	8.7	8.2	—	9.5	10.1	8.2	9.3
root	height	24.2	—	—	—	—	26.2	—	21.0
	length	8.5	7.2	6.2	—	—	7.8	7.8	7.0
	breadth	10.8	9.3	8.2	—	—	10.2	8.7	9.0

The lower canine of recent man (fig. 63) appears to be a very small and slender tooth with a narrow and high crown and the cutting edge tapering off to the tip from both sides when compared with *Sinanthropus*. A cingulum is completely absent and the same is true for the marginal basal prominences. Only the lingual surface may reveal some peculiarities resembling the feature in question in the *Sinanthropus* canine. This surface is usually rather plain and does not show distinct patterns, the center may occasionally be slightly deepened with a minor median elevation and the border faintly folded inward. In certain other cases, however, this relief may be more pronounced and the border more developed with the surface itself deeper than is usual. In addition, a median knob-like swelling may occasionally be observed in the region of the tip. With the exception of the size (height and robustness) the roots do not exhibit essential differences in structure between recent man and *Sinanthropus*.

One of the most striking dissimilarities between the canines in question, however, is the appearance of the edge. In recent man there exists a real tip, that is to say the edge rises gradually from both mesial and distal sides up to the middle line and terminates there in a distinct point which at the same time also serves as the end of an indistinct median ridge more pronounced on the buccal than on the lingual surface. In *Sinanthropus* the edge runs horizontally at first and then suddenly is crowned in the middle by a small conical tip. It seems rather strange when, at first sight, it is found that the shape of the canine of recent man approaches the tooth structure of apes more than is true of *Sinanthropus*. The explanation for this difference will be found when making a comparison of the canine of Neanderthal man with the two groups in question.

Of the Neanderthal group four canines with no trace of attrition are available: one belonging to the Ehringsdorf child and described by H. Virchow (1920), two to the Mousterian youth also studied by H. Virchow, one to a Krapina mandible described by Gorjanovic-Kramberger (1906). The Ehringsdorf canine (fig. 57) is just in the stage of eruption with the base of the lingual part still embedded within the border of the alveolar process. The crown as a whole is stouter than that of recent man and resembles the crown of *Sinanthropus* in this respect (compare fig. 57, *b* with figs. 50, *b* anl 63, *b*). Yet a cingulum is completely lacking on the buccal surface and the marginal prominences are also missing (figs. 57, *b*, *l*; 50; 51; 55). According to Virchow the lingual surface shows a shallow deepening without a median ridge, with no indication of the existence of a basal tubercle and a low rim. As figure 57, *l* demonstrates the distal part of the latter exhibits some striations like those found in *Sinanthropus* (figs. 50; 52, *l*). The canine of Le Moustier, according to Virchow, bears an incisor-resemblance, displaying a median ridge, a basal tubercle and very pronounced rims. Virchow emphasizes that this canine is of a more significant appearance than that of the Ehringsdorf child. As to the Krapina canine, figure 58 shows that its general shape resembles that of recent man. The lingual surface illustrated by Gorjanovic-Kramberger reveals several characteristic details such as the very pronounced rims with indications of superposed rims (marginal contours) on the mesial side and a deep furrow on the distal; the center is occupied by a median ridge which terminates into a well developed and thickened tip. A cingulum is lacking. In spite of the fact that the shape of the crown of the Krapina canine shows a similarity to that of recent man, yet in certain other features it approaches the *Sinanthropus* tooth specimen.

H. Virchow pointed out the appearance of the cutting edge in particular. Like most of the other authors he had expected the Ehringsdorf mandible to be equipped with a long and well pointed canine and was very surprised that instead he found the mesial part of the edge forming a horizontal line (fig. 57). According to the same author the canine of Le Moustier exhibits exactly the same structures as the Ehringsdorf child and with it proves that we are dealing in both cases not with accidental and individual variations but with a peculiarity characterizing the Neanderthal group.

The pictures and descriptions of the Neanderthal canines show very impressively that they represent intermediary forms between *Sinanthropus* and recent man, although they approach the latter more than the former, especially the Krapina canines. Unfortunately, the right canine of the Heidelberg mandible is too strongly worn and damaged to permit a complete comparison, but nevertheless the stump reveals that this tooth does not differ essentially from that of recent man. The intermediate character of the Neanderthal canines is made obvious by the configuration of the cutting edge. The latter in the *Sinanthropus* tooth runs horizontally and bears a small tip in its middle. In the Neanderthal canine only the mesial part of the edge retained its original horizontal course, whereas its distal part declines immediately from the tip. In recent man also the mesial part has lost its horizontal course, thereby giving the canine the appearance of a well pointed tooth. Only in some cases of recent man, such as illustrated in figure 59. the original Neanderthal type may be preserved.

There is no other phenomenon which discloses the secondary nature of the dentition of recent man more than the transformation of the cutting edge of the lower canine. The pointedness and with it its resemblance to the ape tooth is not at all a primitive character as it may seem at first sight. In reality, the lower canine of hominids originally was much more like an incisor than a true canine, the tapering point in recent man having been acquired as a consequence of the process of reduction which transformed the primary large and stout fangs into an ordinary small and slender tooth.

When compared with the lower canine of the great apes the *Sinanthropus* specimen shows great differences, even if such less specialized canines as those of female orang or chimpanzee are taken to serve as examples. All these canines are high and sharply pointed conical or pyramidal structures with the special patterns of the crown confined to a narrow basal band as illustrated in figure 245. Here only a heel-like lingual projection may be observed to be enclosed by a well developed and irregularly bordered cingulum, which combined correspond to the basal tubercle. On the mesial side this cingulum continues into a fine rim rising toward the tip of the tooth. The lingual surface is provided with a sharp ridge running from the tip toward the cingulum and dividing the surface into two slightly concave areas. The lower canine of *Sinanthropus* with its incisor-like appearance therefore differs in principle from the lower canine of anthropoids.

Gregory (1921) in describing the dentition of the Mousterian youth called attention to the fact that its lower canine tends to be aligned with the incisors rather than with the premolars. The same is true of the *Sinanthropus* lower canine. Gregory emphasized in particular the conditions of the cingulum in continuing from the bases of the lingual surface upwards into the mesial and distal borders of the crown and representing thereby highly primitive features as found in Eocene lemuroids. Indeed, the relation of the cingulum to the borders as is apparent in figures 52, *l*; 53 *l* and 56 also strikingly resemble the conditions of living prosimians; figure 300 shows that in *Perodicticus* the rim of the "third incisor"—a transformed canine—continues directly into the cingulum and the same holds good for the "canine" —the transformed first (second) premolar. The denture of this Nycticebide exhibits furthermore that the lingual cingulum rises on both mesial and distal sides but always extends to a higher level on the former side than on the latter. These are exactly the conditions characterizing the canine of the fossil orang (fig. 61) and of *Sinanthropus* (fig. 50, *m, d*).

As already stated above, the lower canine of *Sinanthropus* looks more like an incisor than a real canine, yet the incisor which has the closest resemblance is not the lateral lower but the lateral upper one as a comparison of figures 50, *l* and 261 and figures 19 and 251 will reveal. The upper canine of *Sinanthropus* does not display similar relations, whereas in recent man the similarity between this tooth and the upper lateral incisor may be found to be very close in some cases (compare fig. 59). This appearance together with the obvious dissimilarities between the upper and lower canines of *Sinanthropus* demonstrates that, despite some features in common, the two canines have to be considered as differentiations of a primarily unequally constructed tooth. Such inequalities of upper and lower canines are very characteristic for the primates in which they occur in all orders, especially in that of the prosimians. Whether the canines of the anthropoids originally were also of different appearance and have since undergone a subsequent assimilation as is manifest in recent man cannot be decided on account of lack of suitable fossil material, although I am inclined to believe that such is the case.

Bolk (1914) did not consider the similarities in appearance of the upper and lower canines of recent man as a consequence of reduction but rather as a better retention of the original conditions of their primary stage of evolution by the canines than by the other teeth. That author considers a well pointed canine with a lower accessory tip on each side as the type of origin of the "protomer" and the basal tubercle as the remainder of the "deuteromer" as has been explained in connection with the incisors. In view of the *Sinanthropus* canines, however, all these interpretations will have to be dismissed for they reveal that conditions existing in recent man are without doubt of secondary nature and incontestably a result of a gradual reduction in the course of human evolution.

According to Adloff (1931) a principal difference should exist between the canines of anthropoids and those of hominids, with the former having the basal tubercle developed only in incisors, while in the latter it occurs both in the canine and incisor. If the canines of hominids should have been similar at any time to those of anthropoids, then the hominids must have first lost the tubercle in question and later acquired it again. The presupposition for such a conclusion is apparently incorrect, for Remane (1927) has already proven that a lingual cingulum with a distinct basal tubercle may also occur occasionally in recent anthropoids (compare figs. 245 and 246), and in addition, the canine of the fossil orang illustrated in figure 61 shows a very strong cingulum as well as a strongly developed basal tubercle. On the other hand, the upper and lower canines of *Sinanthropus* (figs. 38, 39, 42, 43, 50-55) show exactly the same features. Thus, there exists no principal difference between anthropoids and hominids in this respect both of which had originally been in the possession of well developed cingula and tubercles. In contrast to Adloff's conception the reverse turns out to be true, namely a surprising parallelism in the evolution of the canines in anthropoids and hominids inasmuch as a progressive reduction of cingulum and basal tubercle occurred in both primate groups with the effect that within most of recent individuals the two structures disappeared completely and may only be found occasionally to be developed in a more or less moderate degree.

In the great apes the crown and the root of the upper canine are not only more robust and higher than those of the lower dentition but there is also a striking difference in shape. The crown of the upper canine is longer in mesio-distal direction and narrower in buccolingual diameter than that of the lower canine which is developed in exactly opposite directions. This difference is apparently a consequence of the quite different manner in which both canines function The upper canine overlaps in longitudinal direction the distal surfaces of both the lower canine and the first lower premolar facing and more or less approaching each other, hence the greater length of this canine, whereas the lower tooth interlocks into the diastema between lateral upper incisor and upper canine rather in transversal direction and hence the greater breadth of this tooth. Such differences in length and breadth are characteristic for canines of all monkeys and great apes. In taking the breadth in percentage to the length, I arrived at the following values:

	C'	C,
Adult gorilla:		
male and female	78.5	128
Adult orang.		
female	86.0	137
Chimpanzee:		
male	80.0	140

The values quoted by Drennan (1929) after Campbell (1925) are:

Gorilla	80.0	138.1
Baboon	68.9	153.3

The corresponding ratios computed on the basis of de Terra's (1905) figures are:

Gorilla:		
male and female	89.7	112.0
Orang:		
male and female	92.2	124.7
Chimpanzee (male)	89.6	116.1

In rare cases of male and female individuals of gorilla and orang, however, the length of the upper canine may be smaller than its breadth, and still more rarely the breadth of the lower canine smaller than its length. As Remane (1927) recorded only the minimum and maximum values of each measurement, it is impossible to compute the corresponding ratios.

In *Sinanthropus* no such difference exists between upper and lower canines in this regard. In the upper as in the lower the breadth is greater than the length, the ratio varying from 100 to 115. The average ratio of the upper canine amounts to 108% and that of the lower to 106%. Thus the upper canine of *Sinanthropus* is shorter in mesio-distal diameter and the lower canine narrower buccolingually when compared with monkeys and great apes.

The average ratios for recent man as compiled by Drennan (1929) and partly computed by Campbell (1925) are as follows:

	C'	$C_,$
European	105.3%	114.5%
Japanese	108.9%	116.2%
Australian	107.1%	109.2%
Bushman	104.1%	103.7%

A comparison of these figures with those of *Sinanthropus* does not reveal fundamental differences and such as there are only concern the Bushman and Australian both of whom approach *Sinanthropus* closer than European and Japanese and in that the lower canine in the latter are broader than long. The frequently discussed problem, namely whether the canine of the first hominids has been more anthropoid-like in size than the *Sinanthropus* specimen or whether they did not differ principally from the latter to any extent will be discussed below.

Upper and lower canines of *Sinanthropus*, in spite of some differences in details, have in common certain accessory longitudinal ridges and wrinkles of which the buccal ones are in the form of fine ribs, coursing on their lingual and buccal surfaces. As also in the case of the incisors, I consider these patterns as an indication of the same general tendency toward the ribbed structure of the dental surface, a phenomenon most characteristic for anthropoids and primitive hominids.

The measurements of height of roots recorded above show that the root of the lower canine is slightly higher than that of the upper one. All questions concerning the size of the teeth will be discussed separately.

3. PREMOLARS

The premolars of *Sinanthropus* are not only of great interest because of their specific appearance but also because of their close relations to the canines. Remane (1927) when discussing the problem concerning the canines of man was the first to realize the importance of thorough investigations of premolars, these and the former partly depending upon each other in the configuration of their characteristic appearance.

a. UPPER PREMOLARS

First premolar (figs. 64, 65, 68, 73, 127, 259, 260, 262, 264, 267, 268, 277, 345)

It is strange that only one isolated tooth (fig. 64) is available. In connection with jaw and skull, five specimens are at a hand two of which are badly damaged. Judging by the size three of the total number available belong to the large type and thus belong to male individuals and three to the small and to female individuals. The fact that this attribution is correct has been verified by the recovery of two large teeth, together with the large male Skull I of Locus L and two small types together with the small female Skull II of Locus L (figs. 73 and 264). The identification of the isolated teeth was made without any difficulty because of their peculiar features.

The first premolar is characterized by its great size and robustness of both crown and root, the robustness of the former (length × breadth) even exceeding that of the canine (compare Diagr. 1). The crown is much more developed in buccolingual direction than in mesiodistal (fig. 64) and is divided by a deep longitudinal furrow into a larger buccal and a smaller lingual moiety both of which carry large cusps, the buccal cusp being considerably larger and higher than the lingual (fig. 64). When viewed from the mesial or distal side it may be seen that both buccal and lingual surfaces are strongly inclined toward the tips of their respective cusps. The buccal surface is oval and slightly longer than high (fig. 64, *b*), although the enamel reaches further upward on this side than on the lingual. The entire basal part projects and continues into a triangular swelling the apex of which merges with the tip of the buccal cusp. Each of the sides of the swelling is bordered by a faint depression and these again are bounded by ridges, faintly developed on the distal side but very pronounced on the mesial. These ridges together with the basal prominences represent the cingulum (fig. 64, *m*, *d*) which rises on both sides as has been described above when discussing the canine. As is revealed by the occlusal view (figs. 64, 65, *o*) the triangular swelling does not occupy the middle of the buccal surface but instead has clearly shifted mesialward. The lingual surface with its equal roundness resembles a part of a ball faintly tapering off toward the summit of the lingual cusp. There are no depressions or bordering ridges. The mesial side of the crown (fig. 64, *m*) resembles closely the corresponding side of the upper canine (compare figs. 38 and 39, *m*). Both here and in the upper canine the buccal cingulum rising toward the edge of the buccal cusp has transformed into a triangular-like swelling with a basal depression and becomes distinct in the region of the lingual cusp. On the distal side (fig. 64, *d*) this feature is only faintly indicated but nevertheless still recognizable. The occlusal view (fig. 64, *o*) is of special interest. The actual chewing surface is delimited by sharp ridges running on each side from the tips of the two cusps downward and toward the intermediate longitudinal furrow and is represented by the buccal and lingual slopes of the cusps facing each other. The contours of the ridges of the buccal part form in occlusal view a winged pattern while those of the lingual part represent a triangular structure. Both these slopes are uneven and are covered by transversal secondary ridges descending from the tips of the cusps. These ridges slightly diverge to the longitudinal furrow and thereby divide the area concerned into several sections. The slope of the buccal cusp shows two such ridges situated closely together and separated by a short and narrow groove. On either side of these ridges there is one somewhat large depression bordered by the marginal major ridge. The pattern of the slope of the lingual cusp is not as regular as the one just described on account of the presence of more accessory and finer ridges, which, however, also diverge from the tip of the lingual cusp. The two mesial ridges of the latter correspond to those of the buccal cusp.

The root of the premolar is like the crown short and broad, that is to say, it is extraordinarily strongly developed in buccolingual diameter (figs. 64; 65; 68; 73, *c*, *d*). In the case given in figure 64 the root not fully developed is divided into two diverging branches, a larger buccal and a smaller lingual one. The former shows on the mesial side a fairly deep furrow (fig. 64, *m*) thereby indicating the tendency to divide the buccal branch into two parts (fig. 325, *a*). At the base the branches are fused together. The difference in size of the two main branches is very apparent in lingual view, the longer buccal branch (figs. 64 and 65, *l*) projecting on both sides beyond the lingual one. Toward the apex both branches bend toward each other. In the cases illustrated in figures 65 and 68 and 73 the division of the root is not as complete as the one of figure 64, as there both branches are united and only separated by deep furrows on the mesial and distal sides. The root as a whole is very stout and bulges at the middle of its height buccal- as well as lingualward. Toward the end the root is tapering off abruptly and branches out into two separate apices of about the same height each of which is thick and rounded and more or less bent toward the distal side. Also in cases in which the roots have fused the buccal part of the root is always larger than the lingual and the former shows traces on the mesial side of a sub-division into a third (buccal) branch (compare figs. 68, *m* and 64, *m*). The neck is slightly constricted but beyond that the root bulges in the manner already described above.

It is worth noting that in each of the three cases the enamel reaches considerably further upward on the buccal than on the lingual side. This feature together with the mesially directed projection of the cingulum part of the buccal surface gives rise to the so-called "tuberculum molare." In conjunction with the latter there is another formation, namely that as seen in the case of the premolar of figure 64 in which the root is divided into two branches such as just described (fig. 325, *a*). The slightly oval lingual branch runs with its longer diameter buccolingualward, whereas the distinctly oval buccal branch is so arranged that its greater diameter takes an oblique course from the mesiobuccal side to the distolingual one. Its mesiobuccal part projects in the same direction as the relevant part of the crown, that is, mesiobuccalward. This arrangement apparently is in close connection with the formation of the tuberculum molare. Figure 325, *a* illustrating the tooth in question viewed from the apical side shows very clearly the position of the branches in relation to each other and to the crown. It may also be observed that the subdivision of the buccal branch takes place in such a way that the small lingual and more mesially situated part becomes separated from it. In figure 68 also the oblique orientation of the buccal branch of the root may clearly be seen.

TABLE IX

Measurements of upper first premolars

64. [illegible] | 65:72:259:214:21[illegible] | [illegible]

		No. 19 ♂	No. 77 ♂	No. 78 ♀	No. 142' ♀
crown	height	9.7	(7.2)	—	(5.2)
	length	9.2	8.7	7.4	8.0
	breadth	12.8	12.6	10.5	11.6
root	height	(13.1)	20.4	20.0	—
	length	7.2	6.9	5.5	6.2
	breadth	12.7	12.8	10.4	10.8

The upper first premolar of recent man (fig. 69) has a strikingly different appearance from that of *Sinanthropus*. Firstly, in size. Even when compared with the smallest (female) specimen of *Sinanthropus* (fig. 68) found hitherto, the average premolar of recent man presents a dwarf-like appearance. With respect to details, the crown of the latter is relatively higher and narrower (compare fig. 69, *b*, *m* with fig. 64, *b*, *m*) than the *Sinanthropus* crown. The cingulum and the mesial triangular prominence are completely lacking in recent man and the whole pattern of the slopes of the buccal and lingual cusps is reduced to two smooth regular areas separated by a small longitudinal furrow (compare fig. 69, *o* with 64, *o*). The tuberculum molare is indicated only by a very faint swelling on the mesial basal part of the buccal surface. The root, in most cases divided into two branches toward the apex, is low, narrow, regular and looks like a smooth awl or two awls respectively.

As in the case of the incisors and canines there is likewise a great variation in the premolar of recent man. Figure 72 represents an unworn tooth of a male Australian aboriginal. When comparing the latter with that of an average European (fig. 69) and that of *Sinanthropus* (fig. 64, *o*) it will be found that the Australian tooth resembles very close to that of *Sinanthropus* and that it differs considerably from the European tooth structure. The Australian premolar however also lacks the cingulum, the *tuberculum molare* is small and does not project to any extent. Only the pattern of the chewing surface is better developed, even though the original arrangement of the ridges and furrows has been lost. With respect to the form of the root the variability is great. Hildebrand (1908) found one root in 44% of the cases, two roots in 41.6%, while in 14.8% the apex was notched. The occurrence of three roots is very rare although noted in some cases.

With respect to the upper first premolar of the Neandertal man, there is only one available which is not too worn for a comparison with the *Sinanthropus* specimens, namely the premolar of the Krapina man illustrated by Gorjanovic-Kramberger (1906). This tooth (fig. 71) does not differ considerably from that of recent man when compared with an Australian native tooth (fig. 72). The Krapina premolar lacks a cingulum as well as the mesial triangular prominence, nor is there any evidence of a well developed *tuberculum molare*. The pattern of the chewing surface, however, resembles *Sinanthropus* in certain details as for instance the formation of the two buccal ridges and a corresponding arrangement of the lingual ridges. On the other, the longitudinal furrow is not as distinct an in *Sinanthropus* and the depression on both sides of the buccal ridges is markedly deepened to form distinct transversally directed foveæ. The premolar of Le Moustier (fig. 70) seems to be slightly worn, although I am not certain whether it really is the case. The chewing surface is very smooth and shows only the general pattern without any characteristic details (compare fig. 70 with fig. 64, *o*). There is no cingulum or mesial prominence, but the tuberculum molare is faintly indicated. In regard to the root H. Martin (1923) described it to be double in La Quina, the two branches (a buccal and a lingual one) being united by a bridge which occupies 4/5 of the height.

A comparison of *Sinanthropus*, Neanderthal and recent man reveals that the first upper premolar of recent man as found in the average European races merely represents a very faint image of the original type embodied by *Sinanthropus*. It is a small tooth reduced in all dimensions of crown and root and of which the primary characteristic features have disappeared to such an extent as to make them almost unrecognizable. Only primitive races like the Australian aboriginals still resemble the original conditions in certain details. The tooth of the Neanderthal man has also lost the essential peculiarities characterizing *Sinanthropus* and approaches recent man much more than the latter.

In order to compare adequately the *Sinanthropus* premolar with anthropoid teeth, it is best to take the premolar of *Dryopithecus* first into our consideration. Gregory (1921) has given a very extensive description on the basis of Pilgrim's illustration which is reproduced here as figure 326. The chewing surface of this premolar is crossed by two sharp transverse ridges running from the well developed buccal cusp and terminating at the lingual one. The ridges are located in front and behind the middle of the tooth and are separated by a depression. Such depressions are also found mesially from the mesial ridge and distally from the distal ridge. Gregory designated these depressions as fossæ and distinguishes an anterior, a middle and posterior one. In present anthropoids this pattern is somewhat different. In gorilla (fig. 298) both cusps, especially the buccal one, are much higher and separated by a faint longitudinal fissure on which two transverse ridges descending from the buccal cusp terminate. Only the mesial ridge, however, is distinct while the distal one is rather obscure in most cases. As to the lingual ridges only the mesial one is preserved and forms a broad middle bridge. The premolar of orang when completely unworn shows the main features of the original *Dryopithecus* pattern but with only a faintly developed longitudinal furrow, the only alteration being that in addition to the main ridges described above the entire surface is covered with fine accessory ridges and wrinkles which are peculiar to the orang. The chimpanzee resembles the gorilla in pattern, however, with the difference that both cusps are lower and the longitudinal fissure between them less clear than in the former. With respect to other particularities, a buccal cingulum is very pronounced in all three anthropoids, rising toward the edge of the buccal cusp not only on the mesial but also on the distal side. The base of the buccal surface projects mesialward and thereby forms a distinct *tuberculum molare*. This fact, together with the breadth of the tooth which exceeds considerably that of the length, makes the contour of the anthropoid premolar when viewed from the occlusal side appear so very similar to that of *Sinanthropus*. The same is true to a certain extent of the roots. Usually, the first upper premolar of the anthropoids has the root divided into three branches, two buccal and one lingual one. As has been described by Remane (1927) the longitudinal axis of the cross section of the mesial buccal branch runs obliquely from mesiobuccalward to distolingualward. Figure 325 *b* shows such a peculiarity occurring in gorilla, but according to that same author it is not infrequent that a complete fusion of both buccal branches in chimpanzee and orang and in some cases a fusion even of all three branches is found.

A comparison of the *Sinanthropus* premolar with that of anthropoids fails to reveal any principal differences. The general shape of the teeth, the development of the cingulum and *tuberculum molare*, the special pattern of the chewing surface and the arrangement of the branches of the root are practically the same. The actual differences involve the degree of development of some minor details and are not greater than those existent between the three anthropoids. The *Dryopithecus* pattern of the chewing surface as has been demonstrated by Gregory is really the basic pattern which has undergone certain transformations corresponding to the specialization of these species. It is obvious that *Sinanthropus* comes close to *Dryopithecus*, with the exception, as also true for chimpanzee and gorilla, that the cusps are higher and the longitudinal furrow more pronounced. Statements have been made repeatedly to the effect that man was derived directly from a primitive primate stock without any closer relation to anthropoids. A thorough study of the premolar will show that the *Sinanthropus* tooth and likewise those of other hominids are identical with the premolars of anthropoids, but on the other hand differ considerably from those of primitive primates (see below).

Second premolar (figs. 75, 77, 78, 127, 214, 269, 277, 327, 345)

Our material consists of five isolated teeth, one of which is damaged, three teeth which were recovered together with skull fragments including one in poor state of preservation (Skulls I and II Locus L) and an additional one embedded in the maxilla O 1. Of these nine tooth specimens seven belong to the small type, that is to say we are dealing with female individuals, and two to the large type (male). The identification of this premolar and its distinction from the first one is not as easy a task as when dealing with the other teeth. However, in view of the fact that premolars have been recovered *in situ* (figs. 127, 277, 345), the differences could be defined.

These differences concern in the first place the size as will be evident when comparing the two tooth types, that is to say P^2 is clearly smaller than P^1. Figure 75 represents the various views of P^2 rt of Skull II Locus L and figures 68 and 73 *d-d* respectively the same views of P^1 rt of the same skull. The crown and root of P^1 furthermore is more developed in buccolingual direction than the same structures of P^2. In addition, the root as a whole is more robust and higher in the former than in the latter.

With regard to details, the contour of the crown viewed from the occlusal side represents a fairly regular oval shape (figs. 77, 78, *o*; 327), with the convexity of the buccal surface in the midline. In accordance with this feature there is no overlapping of the enamel at the boundary of the buccal surface as found in P^1 (compare figs. 75, *d* and 214, *m* with 73, *d-d*). The buccal surface is long and low, the cingulum is very well developed and ascends on both sides of this surface toward the cutting edge and as a result thereof the latter shows a middle elevation and a corner-like tip on each side (figs. 77 and 78, *b*). The buccal as well as the lingual surface withdraws toward the edges of the corresponding cusps (figs. 77 and 78, *m, d*) which are of about the same size and height. The occlusal view as a whole presents the same aspect as that of P^1; the ridges bordering the chewing surface proper form a winged and a triangular pattern, and the slopes of both cusps are covered by accessory ridges and wrinkles showing approximately the same arrangement as P^1 (compare figs. 77 and 78, *o* with 64, *o*). In figure 327 the duplication of the middle accessory ridge of the lingual slope is very distinct. It seems as if the arrangement of the ridges on the buccal slope were not as regular as was described for P^1 but in view of the limited number of unworn premolars available for comparison, I do not venture to state whether we are dealing with a regular feature or whether there exists a great variation from one tooth to the other. In any case the differences of the pattern in question cannot be very significant.

As to the special character of the root it shows the same peculiarity relevant of P^1. The two roots, fully grown, (figs. 75 and 214) are divided partly by longitudinal furrows into two unequal main branches each with a separated apex, the buccal branch being larger and somewhat higher than the lingual one. As is revealed by figure 75, *m* and *d*, there is also an indication of a subdivision of the buccal branch into a larger primary one and a small secondary, intercalated on the distal side between the main buccal and lingual branches. This arrangement corresponds completely to that described for P^1 and represents a remnant of an originally tripartite root. As in P^1 the neck of the tooth is only faintly constricted so that crown and root form a unity of about the same robustness. The boundary between the two structures constitute in contrast to the condition in P^1 a rather straight line (figs. 75, *m*, *d* and 214, *m*) ascending slightly toward the buccal side.

TABLE X

Measurements of upper second premolars

74 75:267 214 75 12'1:277 327

		No. 25 ♀	No. 26 ♀	No. 27 ♀	No. 28 ♀	No. *86* ♂	No. *87* ♀	1.364 No. *88* ♀	No. *133'* ♀	No. *143'* ♀
crown	height length breadth	(7.5) 7.9 11.3	(6.8) 8.3 11.2	8.3 8.3 12.1	(5.0) 7.2 10.3	(8.0) 8.9 12.5	(5.2) 7.3 10.8	(6.1) 7.4 11.2	8.2 8.8 11.7	(4.6) 7.3 11.1
root	height length breadth	— — —	— — —	— — —	13.3 5.3 10.6	— — —	16.0 5.6 10.6	16.2 5.6 10.5	— 5.8 —	— 5.7 10.8

The upper second premolar of recent man (fig. 76) when compared with that of *Sinanthropus* shows the same differences as was evident in the case of P¹. The very regularly formed crown of recent man is much smaller but relatively shorter and narrower than that of the latter. The cingulum is entirely lacking. Only the triangular shape of the cutting edge (fig. 76, *b*) bears a resemblance to its original feature. Both cusps are more pointed than in *Sinanthropus* and the pattern of the chewing surface is extraordinarily simplified: all major—except the buccal—and accessory ridges have disappeared entirely (fig. 76, *o*), the cusps are rounded and smooth, especially on the surfaces which face each other. Apart from a fine longitudinal furrow deepening on each side which forms triangular pits there is no other feature in particular to be noted.

The root tapers off on all sides from the neck to the apex equally. Shallow longitudinal impressions on the mesial and distal side indicate a tendency toward a bifurcation. According to Hildebrand (1908) two branches have been found in only 7.9% and a single root with two separated apices in 4.5%.

The second premolars of the Neanderthal group do not differ distinctly from the first premolar as a comparison of P² lt (fig. 74) and P¹ lt (fig. 70) of the skull of Le Moustier shows. As a whole and in details these two tooth structures are of practically the same appearance. With respect to the root H. Martin (1923) states that in the man of La Quina there is only a single root which is flattened in mesiodistal direction and divided into two apices. With the exception of a somewhat more pronounced development of the furrows and pits no characteristic difference can be observed to exist between P² of Neanderthal man and that of recent man. It is possible that the chewing surface of the premolar of the Mousterian youth is slightly worn but, even if it should be the case, it could in no way alter the fact that the pattern of the *Sinanthropus* points to a much greater primitiveness.

A characteristic common to anthropoids and hominids is that the second premolar does not differ to any appreciable extent from the first one. Figure 326 shows that the general size, the size of both cusps, the entire pattern of the chewing surface and the arrangement of the ridges are approximately the same in both first and second premolars of *Dryopithecus*. In recent anthropoids (fig. 298) there also exists a great similarity between the two premolars under discussion and the peculiarities by which *Sinanthropus* differs from anthropoids with respect to the first premolar, hold good for the second premolar too.

The description of the two premolars of *Sinanthropus* demonstrated that the general shape of the crown and certain details thereof to be approximately the same in both teeth. Such a conformity is peculiar to all primates. In addition, however, both premolars exhibit a special pattern of the chewing surface characterized by the presence of a certain number of ridges and wrinkles and by their specific arrangement. This pattern is, with the exception of some prosimian families, restricted to the group of anthropoids including hominids as stated above. I shall return to this question when describing the molars. Since the upper premolars of *Sinanthropus* offer an excellent example for demonstrating the real nature of this pattern and the principle involved in its arrangement, I take the opportunity of entering into an advance discussion of certain details.

I had earlier expressed the view that the ridges and furrows occupying the lingual surfaces of the incisors and canines respectively may be identical with similar formations of the chewing surface of molars, with the exception that they are much more numerous in the latter than in the former, at least in *Sinanthropus*. A glance at the occlusal view of the premolars illustrated in figures 64, 77 and 78, *o* reveals that there are two major ridges, one on the buccal and one on the lingual side, which represent the cutting edges of the corresponding cusps. The highest point of each ridge coincides with the tip of the cusp and from here the ridges descend on either side—mesial and distal—toward the midline, that is the longitudinal furrow, where they meet. Outside of this field of major ridges the surface of the cusps is equally convex and smooth but within the area embracing the chewing surface proper, that is to say, the slopes of the cusps opposing each other, the tooth is covered by small and fine ridges and wrinkles the number of which varies. The arrangement of these accessory ridges has been described above in connection with the first premolar.

This description, however, requires to be more complete in certain respects. The accessory ridges, two or more, start from the tip of each cusp and descend divergently toward the longitudinal furrow. Yet in cases in which a distinct tip is missing and the cutting edge represented by a rather straight line, the ridges also start from marginal parts of the edge and then take a more or less direct course toward the main furrow. Because of their arrangement, the spurs of the cusps and the main ridges also form the mesial and distal walls of the chewing surface which permits the development of more accessory ridges and which start on either side of the wall and run toward the center of the chewing surface. This feature is clearly seen in figures 77 and 78, *o*. Thus, we deal with two varieties of accessory ridges (wrinkles), namely with those coursing in transversal and those in longitudinal direction. The former are longer, coarser and in the majority more or less uneven, while the latter are shorter, finer and straighter.

In anthropoids these wrinkles have the same character and the degree of development is dependent upon the individual family within the primate group as will be discussed later. In the Neanderthal man the tendency to disappear is already very pronounced and in recent man, as a rule, the wrinkles have been completely lost with only fine furrows preserved which border the base of the cusps and the mesial and distal walls.

b. LOWER PREMOLARS

In recent man the lower premolars may be distinguished from the upper chiefly by the differences in the outlines of their chewing surfaces, that of the former being rounded and that of the latter more oval. All other details are not sufficiently reliable for a determination. In *Sinanthropus*, especially in such cases in which the lower premolars are unworn and their characteristics therefore preserved, the distinction can be made as easily as in anthropoids.

First premolar (figs. 54, 79, 80, 82, 83, 84, 86, 87, 89, 270, 271, 272, 283, 285, 287, 288, 328)

We have six isolated lower premolars and seven either embedded within the mandibles or found in direct connection. Four of the former are in a very good condition of preservation one of which is entirely unworn. Of the premolars *in situ* two represent germs which were exposed by preparing the jaw specimen and easily removed. These favorable conditions made it possible to undertake a thorough study of the crown as well as of the root and at the same time to record the existing variations. With regard to the probable sex, five teeth belong to the large type and have been recorded as male and eight represent the small type and probably pertain to female individuals.

The identification of the premolar and the distinction between right and left tooth is easily made because of the specific features peculiar to this tooth.

The first premolar is of relatively large and robust construction. Viewed from the mesial or distal side (figs. 79 and 80, *m*, *d*) the bicuspidal character of the tooth is very clear with the buccal cusp always higher than the lingual. For the description of details of the crown tooth specimen No. *80* (figs. 79, 272, *b*) was taken as example. This specimen is an entirely intact germ and belongs to the juvenile mandible B I reconstructed by Davidson Black (compare Weidenreich, 1936 b) and subsequently extracted from its socket. The buccal surface (fig. 79, *b*) appears to be much more like that of an upper incisor because of its great length in relation to the height. The base of the surface is bordered by a broad, rather prominent and well limited cingulum which ascends on either side to the cutting edge, higher upward on the mesial than on the distal side. These ascending parts are separated from the surface itself by very distinct grooves. The surface is vaulted in transverse direction and projects stronger toward the mesial than toward the distal side (fig. 79, *o*). Another characteristic feature is its middle in representing an elevated triangle the apex of which (fig. 80, *b*) forms the highest region of the cutting edge. This edge is a sharply curved ridge with a higher central part and a more or less accentuated corner on each side where the ascending parts of the cingulum meet the edge. The buccal surface occasionally shows (figs. 79, 83, *b*) several distinct striations. The basal cingulum itself considerably overlaps the neck (fig. 79, *m*, *d*); in some cases (figs. 82, 87, *m*, 328) this overlapping is restricted to the mesial half of the surface. As figures 79, 80, 82, 83, 86, 87, 89 show there is a certain degree of variation in the development and distinctness of the described details but the general characters as a whole are always the same.

The lingual surface of the tooth No. *80* presents a strange aspect (fig. 79, *l*). The crown here is considerably lower than on the buccal surface. The lingual rim bordering the chewing surface is equipped in its middle with two small separated and pointed elevations, whereas buccalward from these irregularities of the rim there rises above that surface a conical cusp the lingual slope of which is in connection with the lingual rim and its just described elevations only to a small extent. In contrast to the buccal surface the lingual one is strongly convex in transversal directions (fig. 80, *o*). Here also the transverse projection is clearly unilateral and mainly developed toward the distal side (figs. 79, 80, 82, 86, *o*; 328).

Both of these unilateral protuberances—that on the buccal side projecting mesially and that on the lingual side distally—give the tooth, when viewed from the occlusal surface, a very characteristic aspect. Its contour makes an irregular oval the greater diameter of which forms a distinct acute angle with the mesiodistal main direction of the tooth and does not meet with it in a right angle as may be expected (fig. 329). As this diameter runs from mesiobuccalward to distolingualward the distinction between right and left premolar is easily made.

The middle part of the chewing surface is formed by the slopes of the two cusps and by those descending from their connecting ridges of the mesial and distal sides. Thus, there are buccal, lingual, mesial and distal walls the slopes of which meet by a deep longitudinal furrow terminating with a distinct pit at either end. All these walls are covered by short accessory ridges, those of the buccal wall being developed best. As described above the lingual cusp rises as a more or less isolated cone above the lingual part of this surface (fig. 79, *o*). Both the highest point of the buccal cusp and the tip of the lingual cone are situated clearly mesialward from the buccolingual midline of the tooth.

The appearance of the chewing surface in the other premolars at hand (figs. 80, 83, 84) is the same in principle. There are very essential differences, however, with respect to the lingual cone and its relation to the lingual and buccal walls of the chewing surface. In figure 80 the cone seems to be a real part of this wall itself but located somewhat more buccalwards and leaning against the buccal cusp. The same is true for the tooth illustrated in figure 83. Although in both cases the cone is in close connection with the lingual wall, yet it is evident that it does not represent such an integrant part of it as the buccal cusp with respect to the buccal wall. Apart from this peculiarity the cone itself reveals some interesting features: in the specimen illustrated in figure 80 the lingual side is ribbed by accessory ridges on the side opposite the chewing surface; furthermore, in figures 80 and 84 there is a meandering rim starting from the tip of the cone and continuing toward the buccal cusp in the form of a special accessory ridge (fig. 80, *l*). In all these correlated cases the lingual cone is much lower than the buccal cusp.

In such teeth in which the original chewing surface has become obscure due to attrition (figs. 82, 87, o; 328) the lingual cone may be represented by a rounded swelling of the lingual wall projecting from it toward the buccal cusp. The entire special pattern is lacking, with the exception of deep stroke-like pits on each side indicating the boundary between the buccally projecting lingual cone and the mesial and distal walls. In figure 328 the accessory ridges surrounding the two pits are very pronounced.

The root (figs. 82, 86, 87, 89, 91, 328) of the first lower premolar is very stout, especially if it is composed of two fused main branches as true of three of our specimens. There where only one root exists it forms an equally tapering stem which is far more developed in the buccolingual diameter than in the mesiodistal one. The distal surface is straight, while the mesial one is strongly convex receding lingualwards toward the apex (figs. 87, 89, *d*). The longitudinal axis of the root deviates slightly distalwards. Both mesial and distal surfaces are divided by longitudinal median furrows into a buccal and lingual portion.

In cases in which these furrows are deeper impressed (fig. 87) the impression is always more pronounced on the mesial than on the distal side, thus dividing the root into a larger buccal and a smaller lingual portion, each of them having an individual apex. The buccal portion again shows traces of division and also on the mesial surface. In figure 91 the root of the tooth of figure 82 is illustrated viewed from the apex and the buccal and distal sides. Here it is evident that we are dealing with two fused branches, a large buccal and a smaller lingual one, the former seemingly composed of two portions, namely of a main portion projecting mesialwards and a smaller one attached to its mesial and lingual sides. The furrows found in single-rooted teeth together with the strong convexity of the buccal surface of the root apparently must be considered as an indication of the existence of two branches originally.

The relation between crown and root is very well demonstrated by figure 82. In this specimen the root appears as a mere enamel cap over the top of the root. There is no trace of a well developed constriction of the neck region which, it is true, may be more pronounced in other cases. The cingulum overlapping the buccal boundary, especially on its mesial side, has already been described above.

The description and illustrations include the lower premolar recovered in 1926 in Locality I of Choukoutien and described by Zdansky (1927). As is evident from figure 84 this tooth is a characteristic first lower left premolar of *Sinanthropus* as that author already assumed. Its size suggests that it may belong to a female individual. The very distinct and characteristic oblique course of its transversal axis (fig. 329, *b*) however, escaped Zdansky's notice.

TABLE XI

Measurements of first lower premolars

80:210 87

		No. 20 ♂	No. 21 ♀	No. 22 ♀	No. 23 ♀	No. 24 ♀	No. *80* ♀	No. *81* ♂	No. *82* ♂	No. *83* ♂	No. *84* ♀	No. *85* ♂	No. *103'* ♂	No. *132'* ♂	Zdansky's premolar ♀
crown	height	9.0	(7.1)	(7.2)	(6.4)	(3.0)	8.7	8.5	(7.8)	(8.0)	(6.3)	(8.2)	(8.0)	(6.0)	(6.2)
	length	9.3	8.2	8.4	7.9	8.2	8.8	8.8	9.0	9.1	9.0	9.8	8.1	8.2	8.3 ×
	breadth	10.0	9.2	9.3	10.2	9.4	9.1	10.1	10.6	10.7	—	10.2	10.8	10.3'	8.9
root	height	—	15.1	—	15.7	14.4	—	—	18.1/19.1	18.8	—	17.0	16.8	18.8	—
	length	—	6.0	—	6.1	6.2	6.0	—	6.5	—	—	6.6	6.1	6.5	6.6
	breadth	—	7.5	—	8.6	8.7	8.6	—	9.6	—	—	9.7	9.3	8.8	8.5

84:329

The first premolar of recent man (fig. 85) when compared with that of *Sinanthropus* presents an entirely different aspect. Only the general appearance seems similar. The greatest differences between these two types concern the size, the proportions of the crown and those between crown and root, the special feature of the crown and the pattern of the chewing surface. Like all other teeth as has been shown above, the premolar of recent man is merely a small and entirely simple tooth which has lost most of its characteristic features.

To begin with the crown, one of the most striking differences between recent man and *Sinanthropus* is the proportion between height and length of the crown which is low and long in *Sinanthropus* while in recent man it is high and short (compare fig. 85, *b*, *l* with figs. 79, 80, 83, *b*, *l*). A cingulum and its differentiation is entirely absent in recent man, with only the enamel slightly overlapping its buccal boundary (fig. 85, *m*). The crown viewed from the occlusal side is almost completely symmetrical, a peculiarity which caused Bolk (1914) and de Jonge-Cohen (1920) to consider the first (and the second) premolar as the ideal prototype of the mammalian tooth, each composed of a pointed proto- and deuteromer. In figures 85, *o* and 273, *e*, *f*, this symmetry is not as perfect as in typical cases of recent man (fig. 273, *d*) the transversal axis still deviating slightly in the former in oblique direction (fig. 329, *e*), but according to Lenhossek (1922) it is the usual appearance. Apart from this symmetry the entire crown is simplified. Instead of the more or less isolated lingual cone, a low and minute elevation located at the middle of the lingual rim itself or more frequently somewhat nearer the mesial side marks the region in which the cone in *Sinanthropus* rises. This elevation is in connection with the smooth lingual slope of the buccal cusp by a low and rounded transversal ridge running in the midline and separating the surface in question into approximately equal portions, a mesial and a distal one, the most characteristic features of which are deep slit-like or triangular pits on either side. The original asymmetry in favour of the distal side is indicated by the distal pit being always somewhat larger than the mesial one. All ridges are rounded off and the accessory ridges are absent or at best outlined by indistinct irregularities of the surface the most common of which are the small longish tubercles descending from the main ridge of the buccal cusp on each side of the middle transversal ridge (fig. 272, *d*). Of course in recent man also there are many variations the most important of which considered from the phylogenetic standpoint are those concerning the development and the location of the lingual cone or its substitute of the lingual rim. The case illustrated by figure 272, *d*, for instance, somewhat resembles *Sinanthropus* of figure 272, *b*, while figures 272, *e* and *f*, show a similarity to *Sinanthropus* of figure 272, *c*. The division of the lingual cusp into two by a median fissure and not infrequently found in recent man has to be considered as a secondary variation, and it may be that it could also be traced back to *Sinanthropus* like the case illustrated by figure 79, *l*, in which the upper border of the lingual rim shows a similarly small fissure.

The root of the first premolar of recent man is usually represented by a single awl-like and equally tapering fang with a greater buccolingual diameter (fig. 85), and the apex slightly bent mesially. Besides the differences in robustness and height and the convexity of the buccal surface in *Sinanthropus*, there are no essential differences between recent man and *Sinanthropus* when compared with such cases as illustrated by figures 87 and 89. While indications of the occurrence of bipartite, even of tripartite roots are very commonly found in *Sinanthropus* as shown above, yet such occurrences are extremely limited in recent man. I shall return to this question later.

The first premolars of the Neanderthal man in so far as they are intact and sufficiently well preserved to permit an adequate comparison with *Sinanthropus* prove rather convincingly the great gap separating the latter from the former and at the same time the closest approach of Neanderthal man to recent man. According to H. Virchow (1920) the first right premolar of the Ehringsdorf child in the stage of eruption looks somewhat strange when compared with the corresponding tooth of recent man, although there is not the slightest trace of an anthropoid-like appearance recognizable. Virchow's description is confined to the statement that the buccal surface of the tooth shows a swelling above the enamel border which flattens toward the tip of the cutting edge and that the lingual cusp represents a large isolated tubercle continuing buccalwards into a ridge which rises toward the lingual slope of the buccal cusp ending there before reaching the tip. This lingual tubercle is separated from the remaining lingual wall by a sharp fissure on each side. Figure 92, *b*, *o*, is a copy of Virchow's photographs of this tooth. *It is true*, there is no indication of the presence of a cingulum or of other features characterizing *Sinanthropus*, except the fine ridge running along the lingual tubercle toward the buccal cusp (compare figs. 92, *o* and 80, *o*; 84). The Ehringsdorf tooth is totally symmetrical and the lingual cone is replaced by an isolated tubercle interposed within the lingual rim. The first premolar of the Mousterian youth (fig. 94) closely resembles that of the Ehringsdorf child (fig. 92, *o*) in its general appearance, but it differs from it by its asymmetry, the tip of the buccal cusp and the well developed lingual tubercle located closer to the mesial side thereby forming a much larger distal pit than is true on the mesial side. Although the buccal cusp of the first premolar of the Heidelberg mandible (fig. 95) is badly worn, there is sufficient of it preserved to permit a definition of the real character of this tooth. This tooth shows the same feature as that apparent in the Ehringsdorf child, the large lingual tubercle being separated from the remaining lingual wall by distinct fissures on each side and the mesial and distal pits being deep and distinct. An asymmetry with respect to arrangement of cusps and outline of tooth does not exist. Likewise different from the *Sinanthropus* type is the premolar of Krapina (fig. 93) which resembles closer to that of recent man, there being only a fine ridge of the lingual tubercle visible like in *Sinanthropus* and the Ehringsdorf child, and a slight asymmetry in favour of the distal pit and faint traces of accessory ridges on the buccal rim. With respect to the roots of these premolars of Neanderthal man exact information is lacking, with the exception of H. Martin's brief statement (1923) to the effect that in the man of La Quina both mesial and distal surfaces of the root are furrowed in longitudinal direction.

A comparison of the first premolar of *Sinanthropus* with the corresponding tooth is of the greatest importance with regard to the problem of human evolution. Like the canine this tooth has at all times been used as an example to prove that there cannot be any direct relation between hominids and great apes on account of fundamental differences in its shape. In typical cases (figs. 88; 90, *a*; 240; 241; 329, *f*) the premolar is prolongated in mesial and buccal directions so that its main axis runs obliquely from mesiobuccalward to distolingualward. In addition the whole tooth is strong and high; the buccal cusp and its tip being well developed and its cutting edge long and sharp give it the aspect of an irregular pyramid. The cingulum is not distinguishable from the far projecting basal swelling of the buccal surface but towards both mesial and distal ends of the cutting edge there rises from this swelling a rib which corresponds to the ascending part of the cingulum described in the case of *Sinanthropus*. A distinct lingual cone or cusp is absent, instead there is sharp ridge which descends from the tip of the buccal cusp downward and distalward and terminates by a strong rim on the lingual distal corner of the chewing surface. This lingual ridge divides the lingual slope of the buccal cusp into a mesial and a distal surface, each being slightly depressed (compare fig. 329, *f*).

The strong development of the elongated buccal cusp with a well pointed tip and a sharp cutting edge, specially pronounced in its mesial portion, act in collaboration with the corresponding differentiations of the upper canine and give the premolar its peculiar sectorial character. Remane (1927, 1931) has proven, however, that this specialized tooth in particular displays an extraordinary variability in anthropoids. This is especially true for the female individuals of chimpanzee and orang. Figures 81 and 272, *a*, show the premolars of a male chimpanzee which approach that of *Sinanthropus* (fig. 79) so closely that a direct relationship between them can no longer be doubted. In both cases there is a well developed cingulum on the buccal surface ascending to the mesial and distal corner of the cutting edge and continuing lingualward into a strongly projecting basal lip-like protuberance. Between this protuberance and the lingual slope of the buccal cusp a low cone rises separated from the buccal cusp which corresponds completely to the lingual cone described above of *Sinanthropus* (fig. 79, *l*). The only difference between these teeth is that the differentiation of the cingulum is more pronounced and the lingual cone less isolated in chimpanzee than in *Sinanthropus* whereas the asymmetry is even more distinct in the latter than in the former.

As to the roots of anthropoid premolars the same variability exists. Generally they are equipped with two roots but occasionally they may also be found to have fused into one in all three anthropoids (Remane, 1927). Figure 90, *a*, shows the normal bipartite root of P_1 rt of a male chimpanzee viewed from the mesial side with the buccal branch clearly projecting mesialwards. Figure 88 shows P_1 rt of a *fossil (male ?) orang* with a distinct broad cingulum on the buccal surface and a fused root apparently consisting of two portions, a larger buccal one projecting mesially and a smaller lingual one with a deep longitudinal furrow. This feature is very similar to the condition observed in *Sinanthropus* (compare figures 88 and 90 with figures 82 and 86, *m*).

One of the most commonly used arguments in discussing the problem concerning the relation between hominids and anthropoids (see Adloff's publications) is the supposed primitive character occasionally distinctly developed in the former. This primitiveness which is not restricted to the anthropoids but rather represents a general peculiarity of the lower primates and, hence, may be preserved in hominids as well as in anthropoids. The fact that the teeth of both these groups have a common primate character is self-evident and requires no further ascertainment. The question, as to how far hominids and anthropoids are closer correlated with each other than with the remaining groups of primate remains open. It is certain that the first lower premolar in all Platyrrhinæ and Catarrhinæ shows the sectorial type and the same is true for prosimians. But in all these groups there is a great variability in the degree of its development, with the latter depending upon the individual relevant species and sex. In any case the premolar of *Sinanthropus* resembles closest that of anthropoids, especially chimpanzee as demonstrated above, but not that of a real or fictitious primate. Hominids and anthropoids thus belong together. I shall return to this question later.

The facts that the premolar of recent man represent only a *Sinanthropus* form strongly reduced in size and pattern and that its simplicity is not a basic one but rather a secondary acquisition do not require further proofs. The latter are furnished by the variation among *Sinanthropus* itself (tending clearly toward the recent man type) and by the premolars of Neanderthal man which, although already closer to recent man, link both opposing groups in question.

Second premolar (figs. 54, 96-98, 101, 103, 273, 274, 283, 285, 287, 288)

Two isolated second premolars and five embedded within their respective mandibles or at least found together with them are available for comparison. Three of these tooth specimens are germs and entirely intact. In one case pertaining to an adult mandible (jaw K) the tooth could be extracted for the purpose of studying the root conditions. With regard to the assumed sex, four show the large type and have to be considered as male, three belong to the small type and thus represent female individuals. The identification of the tooth and the distinction between right and left was easily made on account of the distinct appearance of this premolar.

The *three unworn teeth* (figs. 96, 97, 101) *not only vary in their pattern* but also *in their shape*. The most interesting of them and perhaps the most conspicuous of all *Sinanthropus* teeth is the specimen No. *89* (fig. 97). This tooth is a germ with the crown already fully developed and the root only to a slight extent. It belongs to the juvenile jaw B I reconstructed and first described by Davidson Black (compare Weidenreich, 1936, b). During the preparation Black removed the premolar from its socket, made a photograph (fig. 274) and a cast of it because of its strange appearance and then re-embedded it into the jaw. The present writer, not less surprised than Black over the appearance of this tooth, removed it for the second time and decided to leave the socket empty. As stated above this mandible also had embedded within its alveolar process the germ of the first premolar (No. *80*; fig. 79) described as the *Sinanthropus* prototype (see above).

Viewed from the buccal side the premolar in question (fig. 97, *b*) is long and low. The base of the buccal surface is occupied by a well developed cingulum which rises still within the region of the mesial part of this surface toward the cutting edge but becomes indistinct toward the mesial surface itself into which it continues without a boundary. On the distal part of the buccal surface there is a distinct ridge branching from the basal cingulum and ascending vertically toward the cutting edge.

In this way the median section of the buccal surface or better the buccal cusp is given a special contour. It forms at the same time the highest part of the cutting edge which however does not occupy the midline but is clearly shifted to the mesial side of the tooth. The cingulum overlaps the neck also on this side. Viewed from the mesial or distal side (fig. 97, *m*, *d*) the buccal surface recedes gradually from the base to the cutting edge in lingual direction, while the lingual surface appears to be more equally curved. The lingual surface (fig. 97, *l*) shows no special detail, except a horizontal striation near the base, which continues into the cingulum. The lingual cusp rises as a small pointed elevation above the general level. It is but slightly lower than the buccal cusp and like the latter is clearly shifted to the mesial side.

Viewed from above (figs. 97, *o* and 273, *b*) the tooth has the aspect of an oblique oval with the greater diameter running from the mesiobuccal to the distolingual side. The buccal cusp and the lingual one, being immediately opposite each other, are shifted to the mesial side so that the transversal midline of the tooth passes along their distal base. The entire distal portion of the tooth is occupied by a special projection which extends also lingualwards and is clearly lower than the mesial portion of the tooth represented by the two cusps (fig. 97, *o*, *d*). This lower heel shows a very characteristic pattern: around a pit-like center there are a great number of short accessory ridges arranged like spokes of a wheel and less developed on the side of the cusps. In addition, the mesial wall connecting both cusps is also covered by such wrinkless which are likewise present on the slopes of the cusps facing each other.

The remaining unworn premolars (figs. 96, 101, 103) exhibit the same features as the one just described, namely the cingulum with the ascending ridges on each side of the buccal surface, the mesial location of the two cusps and the heel-like appearance of the distal portion of the tooth. The sole differences concern the degree of development of the latter structure which does not attain the same distinctiveness in all these cases as in the one used for an example. They are manifest in a lesser development of the heel, in a more rounded form of the outlines of the chewing surface and in an irregularity and scarcity of the wrinkles around the heel center. However, in spite of the smallness of the heel and the irregularity in size and number of wrinkles the original character of the distal portion in its nature of an appendix to the main part of the tooth as represented by the buccal and lingual cusps is not difficult to be recognized also in the related cases. If a tooth has been worn to such a degree as to cause the entire chewing surface to form a more or less smooth plane such as illustrated in figures 98 and 103, *o*, the star-like arrangement of fissures occupying the distal area of that surface serves to indicate the original conditions. On the other hand, another important criterion is presented by the differing shape of the contour of the entire tooth and that of the chewing surface proper. Even if the former should have been more rounded, that is to say, the mesiodistal diameter showing approximately the same extent as the buccolingual one (compare figs. 96 and 101, *c*), the chewing surface itself bordered by the surrounding ridges always retains its oblong shape with the mesiolingual diameter being the longer one.

The roots are either broken off or not yet developed among the isolated teeth available, but well preserved in the left premolar of mandible K I (fig. 98) thus made possible to be removed from its socket. Like the root of the first premolar it is compressed in the mesiodistal diameter so that this one is considerably smaller than the buccolingual diameter. The root is equally strong in almost its entire height and is tapering but shortly before its apex. The mesial as well as the distal sides (fig. 98, *m*, *d*) show distinct longitudinal furrows more pronounced on the mesial side and dividing the root into a buccal and lingual section; from the latter a small mesial portion is again subdivided by a deep cleft coursing from the lingual-mesial side. The apex itself is bipartite with the lingual part slightly more projecting than the buccal one. The crown, larger in all its dimensions than the root, is distinctly marked off from the latter, especially when viewed from the buccal side. The overlapping of the enamel on the mesiobuccal side has already been mentioned above.

TABLE XII

Measurements of second lower premolars

		96;273;274 271 No. 29 ♂.	103 No. 30 ♀	97;272;274 No. *89* ♀	101;273;274 No. *90* ♂	54;283;285 cf 307 No. *91* ♂ GT	No. 92 ♀	99;287;285 cf 309 No. *93* ♂.
crown	height	8.3	(8.1)	6.5	7.3	(6.4)	—	(6.7)
	length	9.2	8.7	8.2(9.9*)	9.0	8.5	—	8.7
	breadth	11.1	9.6	8.0	9.8	11.0	8.2	10.9
root	height	—	—	—	—	19.2	—	17.3
	length	6.3	5.7	—	6.2	6.5	—	6.1
	breadth	9.3	7.8	—	9.2	9.6	—	9.7

* greatest length of the crown

The second lower premolar of recent man (figs. 99, 273, *e*, *f*) when compared with that of *Sinanthropus* is much smaller, very regular in its shape and without any complications in its pattern. The crown is high and short and from the neck widens equally toward the cutting edge. The buccal section of this edge forms a low isolated triangle the apex of which represents the buccal cusp. A similar but much smaller and lower triangle covers the lingual section of the edge with its apex representing the lingual cusp. While the buccal cusp occupies the midline, the lingual one has in almost all cases shifted distinctly toward the mesial side. Viewed from the occlusal surface the outline of the crown shows a circular form with the buccolingual and the mesiodistal diameters being about of the same extension. Both cusps are united by a low and blunt transversal ridge interrupted by a saddle and a fine longitudinal fissure. On the mesial as well as on the distal side of this ridge there are circular pits, both of the same size.

The awl-like root compressed in mesiodistal direction is slender and tapers off gradually toward the apex. The crown decreases similarly in its entire circumference toward the neck so as to make the former appear as being only the uppermost portion of this awl.

Like in the case of the first premolar, there is a moderate variation, especially in the pattern of the chewing surface. de Jonge Cohen-Mühlreiter (1928) illustrate some examples (fig. 41, I-IV). All those variations tend to lean toward the same direction, namely first from an asymmetrical arrangement of the cusps, that is closer to the mesial side, to a symmetrical one, that is their location in the midline; secondly, from a pattern complicated by accessory ridges with a star-like arrangement in the area of the distal pit to a simple circular depression and, thirdly, from a bicuspidal type to a tricuspidal one. The latter type is represented in figure 273 *f*. In my opinion such could be traced back to a *Sinanthropus* pattern like those illustrated by figure 273 *c*, *d* in which the original lingual cusp together with the adjoining accessory ridges belonging to the mesiolingual section of the heel (compare fig. 273 *b*) has merged with the two rounded tubercles.

Of the second premolars within the Neanderthal group (figs. 104-106) that of the Ehringsdorf child (fig. 105) approaches closest to the *Sinanthropus* type, at least with respect to the pattern of the chewing surface. This tooth is of the greatest importance because, according to H. Virchow (1920), we are dealing with an unerupted and completely intact specimen. Like in all other cases of Neanderthal man the cingulum and its differentiations are entirely lacking. Likewise there is only a slight asymmetry of the outline of the chewing surface. The pattern of the latter has been extensively described by Virchow but unfortunately he laid greater stress upon the molar-like appearance of the tooth shown by traces of two accessory cusps than upon the general character of that surface. These cusps are represented by insignificant buccal and lingual elevations occupying the distal border of the surface. As figure 105 illustrates the most striking feature to be observed is that the buccal and lingual main cusps, both of which are united by a transversal ridge, have shifted sharply to the mesial side thus rendering the tooth distinctly asymmetrical. The mesial pit located between that transversal ridge and the mesial border of the crown is small, while the distal pit is formed by a large oval area which corresponds exactly to the deepened center of the distal heel described for *Sinanthropus* (fig. 97, *o*). This pit is bordered distally by a buccal and a lingual elevation (Virchow's accessory cusps) and traversed by fine fissures radiating from the center and separated from each other by fine ridges covering the slopes of the two main cusps and of the two accessory ones. There is no doubt that the fundamental arrangement of the pattern of this Ehringsdorf premolar is exactly the same as that of the *Sinanthropus* tooth (fig. 97, *o*). Yet there is one essential difference: although the Ehringsdorf tooth is an unerupted germ, its whole surface compared with that of the *Sinanthropus* premolar is completely smooth and appears more like a worn *Sinanthropus* tooth than an unworn one of the latter (compare figs. 97, *o* and 105) with the result that the two teeth only bear a similarity to each other as regards the principle of their pattern.

The premolar of the Mousterian youth (fig. 104) approaches very closely to the Ehringsdorf tooth just described. As has been noted by Gregory (1921) the distal pit is much larger than the mesial one. In addition, the arrangement of the fissures is exactly the same as in the Ehringsdorf premolar the difference being only in the smoother surface of the former which is apparently due to the stronger attrition of the Mousterian tooth. On the other hand the contour of the chewing surface is oblong with its greater diameter running from mesiobuccal to distolingual direction, a feature which corresponds perfectly to the conditions of the *Sinanthropus* specimen illustrated in figure 97.

Quite in contrast to these two Neanderthal premolars that of the Heidelberg mandible (fig. 106) is completely symmetrical and does not differ in any essential features from those of recent man (compare fig. 106 with fig. 273, *c*).

The second premolar of the anthropoids (figs. 90, *b*, *c*; 102; 107, 108; 273, *a*; 297) shows all the characteristics of the *Sinanthropus* tooth, only in a more pronounced degree of development. When the premolar of chimpanzee illustrated in figure 102 is compared with the *Sinanthropus* tooth of figure 97, the differences are very small and merely concern details of minor importance. The cingulum and the way of its ascent to the mesial border of the cutting edge (fig, 97, *b* and 102, *b*) is exactly the same. The buccal cusp in chimpanzee rises to a higher level and beyond that of the heel-like distal appendix of the tooth than is true in *Sinanthropus*. The shape of the crown, however, as may be judged by the outlines of the chewing surface (figs. 97, *o*; 102, *o* and 273, *a*) is of the same oblong and asymmetrical appearance in both cases and the chewing surfaces display in principle the same patterns, with the only difference that in chimpanzee because of the greater height and distinctiveness of the buccal and lingual cusps the contrast to the distal heel is more pronounced than in *Sinanthropus*. Such a disparity is also evident in the size of the accessory ridges and in that their arrangement is finer and much more irregular in chimpanzee than in *Sinanthropus*. In orang the special character of the heel occasionally is quite clear as in figure 108. The two main cusps and the transversal ridge uniting them are shifted here entirely mesialward so that the mesial pit is restricted to a small depression between that ridge and the mesial border, while the distal pit occupying a great circular area bordered on its distal side by a narrow rim is traversed by many fine wrinkles radiating from the center to all directions. In gorilla (fig. 107) the appearance of the chewing surface is as follows: two cusps, very high and well pointed, are likewise shifted far mesialward, and the ridges uniting them are very narrow and sharply edged, while the distal heel projects far lingualward. The deep distal pit occupies a large area bordered by a high wall with an edged rim and the fine wrinkles confined to the mesial and buccal parts of the wall and the base of the pit.

It is worthy of note that in some cases the mesiolingual portion of the wall surrounding the pit has developed to a really low but pointed cusp. A similar but smaller thickening may occur also at the opposite corner, that is to say, on the mesiobuccal side of the wall. In orang and chimpanzee both places may likewise be marked by more or less distinct elevations, without obtaining, however, the character of real cusps.

With respect to the root Remane (1927, 1931) already called attention to the fact that the primary bipartite root sometimes shows a tendency towards fusing into one single root. In figure 90 the second premolars of the left (*b*) and the right (*c*) side of the same male chimpanzee are illustrated, the former in mesial view and the latter in buccal view. In the right premolar two separated branches, a mesial and a distal one, are present with the mesial branch clearly located much more buccalward than the distal one. In the tooth of the left side (*b*) there is only one root but this root consists of two fused branches, namely a large mesiobuccal branch and a smaller distolingual one. These are exactly the same conditions as in *Sinanthropus* (compare fig. 98, *m* with fig. 90, *m*).

When comparing the second premolars of anthropoids and those of *Sinanthropus* there cannot remain the slightest doubt but that *Sinanthropus* has all his characteristic features in common with anthropoids and that the unimportant differences which exist are not in any way greater than those distinguishing the various families within the anthropoid group. I therefore consider it superfluous to again enumerate the individual features concerned. The statement so often made by certain authors emphasizing that the teeth of recent man do not have anything in common with those of anthropoids and that the peculiarities of the former may be directly traced back to a primitive type of primate has now been completely disproven by the dentition of *Sinanthropus*, especially also by the second premolar. Of course, the heel-like distal appendix and the mesial location of the buccal and lingual cusps are to be found also in lower monkeys and are characteristic for all Platyrrhinæ and Catarrhinæ but the peculiar shape of the tooth, the proportions and the existence of accessory ridges, together with their arrangement around the center of the heel, are specific for anthropoids and *Sinanthropus*.

On the other hand there is a continuous line of regression leading from *Sinanthropus* to recent man with a distinct tendency toward simplification of the entire premolar in question and deprivation of all its complicated patterns. Such a process already took place in *Sinanthropus* as proven by its individual variations described above. In Neanderthal man, as far as suitable material is available of this hominid, this regressive process has already reached a high degree approaching very closely to that of recent man.

c. THE CANINE AND PREMOLAR PROBLEMS

In one of the preceding chapters dealing with the canine it has been demonstrated that the shape of the upper and lower canines of *Sinanthropus* differ from each other considerably. *Sinanthropus* occupies herewith a special position when compared with the anthropoids on the one hand, and with recent man on the other, because the upper and lower canines of the former as well as of the latter show a distinct tendency of becoming more or less equal in their entire appearance. It may be that the disparity in the case of *Sinanthropus* must be considered as the original primitive character peculiar to early lower primates for, indeed, it can still be found in their living representatives. Thus the tendency toward conformity may be considered as a convergency which occurs independently in both anthropoids and hominids. Nevertheless, the fact that the upper canine of *Sinanthropus* reveals a typical anthropoid structure with respect to its entire appearance is evident by its marked resemblance to the lower canine of the fossil orang shown above. The actual problem on the canine, however, does not concern so much the shape and pattern of this tooth but rather its size and more particularly its height. Many authors, strange as it may seem, take this very feature as the only decisive criterion of the classification of a given primate type within the zoological group of anthropoids. In the case of hominids such a standpoint is all the more erroneous, for all remaining peculiarities of the entire body prove incontestably the existence of the closest connection between hominids and anthropoids and show that there is a wide separation of the former from all other groups of monkeys and prosimians. Although I consider the entire question concerning the size of the canine a rather irrelevant matter, yet it should be discussed with regard to the really new facts supplied by the *Sinanthropus* dentition.

The most striking peculiarity of a large and high canine is its projection beyond the level of the adjacent teeth, namely the second incisor on the mesial side and the first premolar on the distal one. Of course, such a projection can only be proven with accuracy if the canine and the adjacent teeth have not undergone a strong attrition. In anthropoids this fact in general does not matter a great deal, since the canines there are so high that even a strong attrition would not alter their preponderance to any great extent. As has been shown by Remane (1931), however, in many cases the attrition causes also here such a complete leveling of the chewing surface that neither the upper nor the lower canine exhibit any signs of projection. A case of this kind concerning an old female orang is illustrated in figure 306. Another fact is revealed in this illustration, namely there are no diastemata to be observed between the lateral incisor and canine for the accommodation of the lower canine nor between the canine and the first premolar to accommodate the upper canine. Remane (1931) has likewise shown that these gaps may be completely or approximately completely absent in anthropoids also, even in cases with well developed canines. The absence of a diastema therefore cannot be considered as proof that a low canine had existed. This conclusion is especially true for the upper canine; for all Platyrrhinæ have very long and pointed upper canines but without the slightest gap between the lower canine and first premolar both of which are in immediate contact in a large number of cases. The same holds good for the prosimians. The reason for this peculiarity is that the upper canine does not interlock between the two lower teeth as much as it overlaps them on their buccal sides. This behavior apparently is the more primitive one.

Indeed, in connection with this feature the first premolar of the Platyrrhinæ has no pronounced sectorial character, being formed symmetrically by two well developed cusps facing each other. Moreover, the diastema of the upper jaw does not depend so much upon the height and large size of the lower canine as upon the difference in the direction of the upper incisors and the upper canines. If the former have an approximately horizontal position as in the case of a strong alveolar prognathism, a wide gap may be found because the canine is not taking part in that projection but keeps its more vertical direction. If, on the contrary, the incisors are placed vertically, then the gap is reduced and may be absent completely even if there should be a high and large lower canine present. Figures 219 and 220 demonstrate such cases for the anthropoids; both figures represent adult female orang, figure 219 illustrating the first eventuality while figure 220 shows the second one. In the orang in figure 220 the lower canine was even much larger than in the orang of figure 219. That the formations of diastemata may primarily be, if at all, only in very loose connection with high canines is furthermore evident when conditions in question are studied in prosimians. Here very wide gaps may be observed without the canines showing a stronger or corresponding development. In his latest publication Adloff (1937) claims that the absence of a diastema proves that a considerable projection of the canine could not have existed because of the hindrance caused thereby to the articulation. The existence of anthropoids without any diastemata and of Platyrrhinæ with very long upper canines and no indication of that feature illustrates very clearly the incorrectness of such an assumption.

In order to decide the question whether or not the canines of *Sinanthropus* project beyond the level of the adjacent teeth, especially beyond that of the first premolar, it is essential to have unworn teeth available. Unfortunately, there is only one of the upper jaw and two of the lower jaw at hand. With respect to the latter in mandible B I the left canine (fig. 50) and the right first premolar (fig. 79) are preserved and in mandible B V the corresponding teeth of the right side (figs. 51 and 83). Measurements of the height of the crowns are as follows:

B I:	C_1 (No. 70)	11.7 mm
	P_1 (No. 80)	8.7 mm
B V:	C_1 (No. 71)	11.7 mm
	P_1 (No. 81)	8.5 mm

In both these cases the crown of the canine is higher by 3.0 and 3.2 mm, respectively, than that of the premolar. A comparison with recent man is difficult because of the lack of measurements of one and the same individual. Lenhossek (1922) recorded the following:

C_1	12.0 mm
P_1	8.5 mm

the difference being 3.5 mm greater than in the case of *Sinanthropus*.

As to the upper dentition the canine No. 16 (fig. 38) and the premolar No. 19 (fig. 64) apparently belong to the same individual (F IV) The height of the crowns is as follows:

F IV:	C^1 (No. 16)	14.2 mm
	P^1 (No. 19)	9.7 mm
	Difference:	4.5 mm

This case is illustrated in figure 260. Reference to this case will be made below. In Lenhossek's case the corresponding measurements are: C^1 11.0 mm, P^1 8 mm, the difference being 3.0 mm. Such a result implies that the crown of the upper canine is considerably higher than that of the first premolar in *Sinanthropus* as well as in recent man but the difference being distinctly greater in the former than in the latter.

As to worn canines and first premolars belonging to the same individual, there are two specimens of the lower jaw and two of the upper one at our disposal. Figures 54 and 285 illustrate the conditions in question in mandible G I and figure 287 those of mandible K I. In spite of the strong attrition the lower canine is higher than the first premolar. In addition the worn surface of the former strongly declines from the mesial to the distal border, a feature which must be taken to be characteristic for *Sinanthropus* because of its occurrence in all the specimens available (figs. 53, 55, 56, 60). This appearance indicates that the upper canine projects beyond the level of the chewing surface and interlocks between the lower canine and the first premolar. Such a feature is also quite common in recent man (fig. 67). If the attrition is still further advanced, then it is possible that both teeth in question have about the same level as demonstrated in figure 66. However in this respect there is no fundamental difference between hominids and anthropoids, a fact which is evident when comparing figure 66 with figure 306.

Of the upper canine there are two cases of which it is absolutely certain that the canine and the first upper premolar belong to the same individual (figs. 259 and 262) The teeth in question of one of these cases pertain to the male Skull I Locus L (fig. 259), the second set of teeth to the female Skull II Locus L (fig. 262). In both cases the two teeth are equally strongly worn but nevertheless the crown of the canine is much higher than that of the first premolar. That which seems to be of special interest, however, is the fact that the male canine considerably exceeds the female one in this respect. One may object to considering this preponderance of the canine crowns in height as a certainty proving that they had actually projected beyond the level of the chewing surface, since it may also be possible that there existed a strong alveolar prognathism with the canines embedded lower within their sockets than the first premolars which do not share in this prognathism. Such a possibility should be admitted even though it is rather irrelevant, for it does not in the least lessen the real preponderance of the canine crown in height. There is an indication, however, that a strong alveolar prognathism, at least one which may have included the canines, cannot have existed in the two cases of worn canines and premolars in question (figs. 259 and 262). The distance of the corresponding contact facets of the canine and premolar from the basal line of the crown formed by the uppermost border of the enamel on the buccal surface is so limited that the tip of the unworn canine must have projected beyond that of the unworn premolar to the same extent as figure 260 shows.

In his controversy with Remane Adloff (1931a) postulated as proof of the pre-existence of a notable larger canine in hominids at least the evidence showing that the canines have in the course of evolution undergone a stronger reduction than the other teeth. Table XIII gives the average total height (crown plus root) of the *Sinanthropus* canines, lateral incisors and two premolars together with the same measurements of recent Japanese, Bushman, Australian and European (according to Campbell, 1925, and Drennan, 1929), and the differences in height of the incisors and the two premolars in percentage.

TABLE XIII

Upper teeth

	total height (average)				difference		
	C'	I^2	P^1	P^2	I^1	P^1	P^2
Sinanthropus	36.4	28.8	28.9	23.2	79.3	79.4	63.8
Japanese	26.4	21.7	21.0	20.7	82.2	79.6	78.5
Bushman	24.2	20.4	21.1	21.1	84.3	87.2	87.2
Australian	27.5	24.5	22.6	22.3	89.3	82.3	81.3
European	26.5	22.0	20.6	21.5	83.1	77.7	81.2
Recent man	26.1	21.1	21.3	21.4	84.7	81.7	82.1

Lower teeth

	C_1	I_2	P_1	P_2	I_2	P_1	P_2
Sinanthropus	35.5	28.6	25.1	25.7	80.6	72.3	72.3
Japanese	24.5	21.3	21.5	20.8	87.2	88.0	85.1
Bushman	23.6	20.6	20.2	20.7	87.4	85.7	87.8
Australian	28.0	24.5	22.6	22.5	87.6	80.7	80.5
European	25.6	21.1	21.6	22.3	82.4	84.6	87.3
Recent man	25.4	21.9	21.5	21.6	86.1	84.8	85.2

With regard to the upper dentition the height of I^2 amounts to only 79.3% of the height of the *Sinanthropus* canine against 84.7% in recent man and the height of P^1 79.4% against 81.7% and that of P^2 to 63.8% against 82.1%. As to the lower dentition the height of I_2 amounts to 80.6% of the height of the *Sinanthropus* canine against 86.1% in recent man and the respective figures for P_1 are 72.3% and 84.8% and for P_2 72.3% and 85.2%.

These figures demonstrate that the differences in height between the canines and the lateral incisors as well as the two premolars are distinctly smaller in recent man than in *Sinanthropus*, or, in other words, the reduction which has taken place in all teeth apparently affected the canines to a greater extent than the other, that is to say, the canines of *Sinanthropus* are not only absolutely but also relatively higher than those of recent man.

This fact is further confirmed by the results obtained for the height and the robustness of the crown. The following two tables show corresponding figures in the manner as Table XIII.

TABLE XIV

The crown height of canines, lateral incisors and first and second premolars of *Sinanthropus* and recent man and their differences in percentage

Upper teeth

	Crown height (average)				Differences		
	I^2	C^1	P^1	P^2	I^2	P^1	P^2
Sinanthropus	11.6	13.9	9.7	8.4	83.6	69.7	60.4
Japanese	10.0	11.0	8.8	7.8	90.8	80.0	70.8
Bushman	7.9	7.9	6.6	6.3	100.0	83.6	78.5
Australian	8.9	7.6	6.3	5.6	117.0	82.9	73.8
European	9.0	9.2	8.2	7.5	97.8	89.2	81.6
Recent man	8.95	8.9	7.5	6.8	100.5	84.3	76.4

Lower teeth

	Crown height (average)				Differences		
	I_2	C_1	P_1	P_2	I_2	P_1	P_2
Sinanthropus	9.9	11.7	8.8	7.5	84.6	75.2	64.2
Japanese	9.7	10.9	9.3	8.0	89.0	85.3	73.5
Bushman	7.1	8.3	6.2	5.9	85.6	74.8	71.2
Australian	9.8	9.9	6.3	6.0	99.8	63.6	60.7
European	9.7	10.3	7.6	7.9	94.2	73.8	76.8
Recent man	9.1	9.85	7.35	6.95	92.3	74.6	70.6

TABLE XV

Robustness of crown (length × breadth) of canines, lateral incisors and first and second premolars of *Sinanthropus* and recent man, and their differences in percentage

Upper teeth

	Robustness of the crown (average)				Differences		
	I^2	C^1	P^1	P^2	I^2	P^1	P^2
Sinanthropus	77	98	102	88	68.7	104.0	89.8
Japanese	45	68	69	65	66.2	101.2	95.5
Bushman	40	58	60	55	69.0	103.3	94.8
Australian	53	76	80	73	69.8	105.2	96.0
European	38	62	65	60	61.4	104.8	96.7
Recent man	44	66	68.5	63.25	66.6	103.7	95.7

Lower teeth

	Robustness of the crown (average)				Differences		
	I_2	C_1	P_1	P_2	I_2	P_1	P_2
Sinanthropus	48	79	87	90	60.8	112.5	114.0
Japanese	37	54	63	60	68.6	116.7	111.1
Bushman	31	48	52	55	64.6	108.5	114.6
Australian	44	63	69	68	69.8	109.3	107.8
European	38	55	55	57	69.2	100.0	103.4
Recent man	37.5	55.1	59.8	60.0	68.2	108.3	109.0

As to the upper dentition of *Sinanthropus* the height of the crown of I^2 amounts to only 83.6% of that of the canine against 100.5% in recent man, that of P^1 to 69.7% in *Sinanthropus* against 84.3% in recent man and that of P^2 to 60.4% against 76.4%. For the lower canine the corresponding figures are: for I_2 84.6% against 92.3%; for P_1 75.2% against 74.6%; for P_2 64.2% against 70.6%. These results show that the crown of the upper canine of *Sinanthropus* is much higher than those of I_2, P_1 and P_2 and that this preponderance decreased during the process of the general reduction experienced by the human teeth in the course of evolution, so that in recent man the relative height of this canine is much less than in *Sinanthropus*. As to the lower canine of *Sinanthropus* this preponderance is also evident but not as pronounced as in recent man. Hence, the upper canine is more involved in the reduction than the lower one; of the lower dentition the first premolar of recent man shows the same degree as the lower canine of *Sinanthropus*.

The results given for the robustness of the crown derived by multiplying its length and breadth (Table XV) reveal different conditions. The upper canine apparently is less reduced in this respect than I^2, equally as much as P^1 and more than P^2, while in the lower dentition the premolars have undergone a greater reduction than the canine.

Thus, the dentition of *Sinanthropus* verifies Adloff's postulation as far as the upper canine is concerned. This canine when compared with the adjacent teeth is relatively higher in its total height as well as in its crown. The lower canine is less involved with respect to the height, while in robustness there is a greater reduction in I_2. but on the other hand P_1 and P_2 are more reduced than C_1. At any rate the canines as a whole have undergone a relatively greater reduction than the other teeth. The preponderance in height of the canines over the adjacent teeth as evident in almost every case of recent man must also be considered as a clear indication of a primarily larger and higher canine.

Remane (1931) attempted to infer the primary occurrence of a larger upper canine in hominids from certain features of the first lower pemolar which he interpreted as presenting a special adaptation to such a canine. There are five points: 1) the preponderance in size of P_1, especially in height, over P_2; 2) the buccal surface of P_1 being larger than that of P_2 when viewed from the occlusal surface; 3) the buccal surface of P_1 projecting further in mesiobuccal direction than that of P_2; 4) the mesial root of P_1 having shifted to the buccal side; 5) the mesial ridge descending from the buccal cusp being longer than the distal one.

The selection of these features shows that Remane considered a sectorial pattern of P_1, characteristic for Catarrhinæ, as the original type of hominids. In the preceding pages I was able to demonstrate that some of those five points indeed are very distinctly realized in *Sinanthropus* and much more prenounced than in recent man. This is especially true for points 2, 3 and 4. It does not prove, however, to be correct for points 1 and 5. For, as diagram 1 reveals, the crown of P_1 is somewhat smaller than that of P_2 in relation to its robustness, while it is clearly higher than that of the latter (Diagr. 10). As to point 5 the mesial ridge is not longer than the distal ridge in the case of P_1 but rather shorter (fig. 79, *o*).

The cause for this divergence from Remane's supposed scheme is the fact that in *Sinanthropus* the two lower premolars show a degree of molarization which has completely disappeared in recent man. This molarization represented by a well developed talonid (distal heel) is somewhat more manifest in P_2 than in P_1. Therefore, the crown of P_2 is larger but lower than that of P_1 and as a consequence of the stronger development of the distal heel the buccal and lingual cusps of P_1 and P_2 are located closer to the mesial border which is tantamount to a shortening of the mesial ridge. In anthropoids like in all Catarrhinæ P_1 in contrast to P_2 does not reveal this molariform character. Thus the question arises whether *Sinanthropus* represents a more primitive or a more specialized form when compared with the anthropoids. The first lower premolar of all great apes, living and extinct, is a distinctly sectorial tooth, that is to say, the buccal cusp is elevated and pointed whereas no lingual cusp can be recognized, at least in most of the characteristic cases. Nevertheless, a lingual cusp exists but is concealed by a prominence caused by the lingual ridge there where in descending from the tip of the buccal cusp it meets the long lingual edge (compare figs. 240 and 241, *b*). In some cases, especially in chimpanzee, this prominence may become more distinct and occasionally also be more separated from that edge, so that it may take on the appearance of a lower isolated lingual cone. Such a case is illustrated in figure 81. This illustration at the same time demonstrates that the tooth may even lose completely its sectorial character and then closely resemble a *Sinanthropus* premolar (compare figs. 79 and 81). I believe that these conditions actually prove the primary existence of a distinct lingual cusp. This cusp disappeared during the specialization of the first premolar, leading to the sectorial type which occurred in all Catarrhinæ, except in hominids, and to a certain extent also in chimpanzee. Thus, the hominids herein retained their primitive character in contrast to the anthropoids. In this respect I agree with Adloff (1908, 1931a) and disagree with Remane (1931).

Remane considers the extensiveness of the buccal surface, its basal protrusion in mesial direction and the strongly buccal orientation of the mesial root (points 2 to 4) as a clear indication of the first premolar having been a sectorial type originally. Such a conclusion, however, is not at all convincing. In agreement with Remane I am also inclined to take the two first features for an adaptation to a large upper canine but not necessarily as the remainder of a real sectorial type of the premolar. For Remane himself distinguishes three types of first premolars differing from each other by their degree of specialization. His "Mycetes-type" is far less specialized than his "Catarrhinæ-type". In reality *Sinanthropus* approaches much more the Mycetes-type than the Cebus-type or the Catarrhinæ type. The oblique orientation of the most prominent basal part of the buccal surface and apparently connected therewith the same orientation of the mesial root in relation to the distal one, in my opinion, indicate that the first premolar was primarily embedded in an oblique direction within the mandible, so that the longitudinal axis of the tooth formed an acute angle opening mesiobuccalward with the longitudinal axis of the mandible. This arrangement of the two premolars in contrast to that of the molars is very characteristic for the primates—prosimians (fig. 300), Platyrrhinæ, Catarrhinæ (fig. 301, *a*). In *Sinanthropus* it may still be found in both premolars as revealed by the direction of the relevant alveoli of the mandible H I (fig. 301, *b*), but occasionally it is less pronounced in the second premolar. In recent man there is a clear tendency towards a plainly transversal direction (fig. 301, *c*), although the oblique arrangement may occur not too infrequently.

This oblique orientation apparently is due to the degree of curvature of the dental arch. In cases in which the anterior alveolar arch (compare Weidenreich, 1936 b: "The mandible arches" pp. 98-112) is prominent, narrow and rounded as is true in all primates, this orientation and its contrast to that of the molars is very striking, while in man with the frontal part of the arch receding and flattened and the premolars, especially the first one, located just at the point where the arch bends, their orientation is more or less in line with the transversal direction of the molars. On the left side of the Heidelberg mandible (fig. 301, *d*) in which the crowns of the premolars are broken off the root stumps demonstrate very clearly such a difference in orientation with the first premolar retaining its primary direction and the second already adapted to the new one. In an earlier publication (1934) I was able to show that the oblique orientation of the premolars is all the more pronounced the longer the snout, a condition clearly demonstrated by baboons. It is obvious that the oblique direction is for the purpose of saving room. In all cases with large lower canines and first premolars of the sectorial type these teeth occupy a much larger space within the mandible than the deciduous teeth which they have to replace. As the first permanent molar erupts before this replacement takes place, it prevents the mandible from growing in backward direction and, in order to obtain the necessary room for the permanent teeth anterior to the first molar, the jaw must grow forward and thereby causes the snout to stretch. In recent man exactly the reverse conditions exist. The lower deciduous canine and the two deciduous molars occupy a larger space than the permanent canine and premolars. The anterior part of the dental arch of the infantile mandible therefore does not only have sufficient room for the permanent teeth replacing the deciduous ones but is even somewhat larger. In consequence of this fact the frontal part of the mandible does not have to grow forward during the second dentition but instead recede backward, thus forming in place of the high curve characteristic for the first dentition an almost straight line.

Sinanthropus follows recent man in this respect. The direct distance (chord) between the mesial border of the deciduous canine and the distal border of the second deciduous molar measures:

juvenile mandible	B I	(♀)	25.0 mm
" "	B III	(♂)	32.3 mm
" "	B IV	(♀)	30.3 mm

The same measurement for the corresponding permanent teeth are:

adult mandible	G I	(♂)	26.0 mm
" "	H I	(♀)	22.4 mm
" "	K I	(♂)	25.3 mm
" "	M I	(♂ ?)	22.3 mm

The average of that distance for the deciduous teeth therefore is 29.2 mm and for the permanent teeth 24.0 mm, that is, 5.2 mm less. Bolk (1926) who was the first to call attention to the fact that a difference existed between recent man and anthropoids in respect to the height and width of the anterior alveolar arch of juvenile and adult individuals, arrived at the following figures for the chord from the midline to the distal border of m_2 and P_3 respectively:

	juvenile	adult
chimpanzee	31.3 mm	40.9 mm
recent man	29.5 mm	28.6 mm

Mijsberg (1931) computed the respective values for the same chords in *Symphalangus syndactylus* which are:

	juvenile	adult
Symphalangus	21.7 mm	27.7 mm

Although these figures are not directly comparable with those arrived at for *Sinanthropus* because they cover a longer distance (reaching the incisors instead of only the mesial border of the canines), yet they demonstrate the existing differences with sufficient distinctiveness.

As in all these cases of apes the deciduous molars are embedded within the mandible with their longitudinal axis parallel to that of the jaw the premolars being in oblique direction, the differences between the two stages of dentition would be still more pronounced if they had the same longitudinal direction as the deciduous molars.

Taking all these facts into consideration I am inclined to conclude that there are various factors contributing to the special appearance of the lower premolars discussed above. The oblique embedding within the mandible apparently is a primitive primate character brought about by the far projecting frontal part of the mandible. This manner of embedding obviously is responsible for the oblique position of the root and, in connection with this, for a stronger prominence of the base of the buccal surface in mesial direction. Thus, a suitable basis has been provided for the function of possibly a large and high upper canine. *Sinanthropus* therefore represents a primitive stage of evolution.

Although I believe that the appearance of the lower first premolar suggests the probability that a still larger upper canine must have existed in the forerunner of *Sinanthropus*, yet there is no distinct evidence proving that the lower canine also must have been essentially larger in the preceding stage of evolution. As noted above, the lower canine of *Sinanthropus* looks much more like an incisor than like the upper canine. It is quite probable that this peculiarity also represents a primitive character.

The fact that the upper first premolar of recent man also shows the tendency to develop the base of its buccal surface in mesial direction, a condition still more evident in *Sinanthropus* (figs. 64 and 65, o), has been interpreted by

Remane (1931) as the effect of "entwicklungsphysiologishe Beeinflussung" by the lower premolar. Such an interpretation sounds rather obscure. It seems to me that the real explanation is much more simple. First of all the development of that basal buccal prominence is a characteristic for all anthropoids and Cercopithecinæ. There, especially in male gorilla with strongly developed upper canines, the base of the mesial branch of the buccal root of the first premolar projects distinctly much more buccalward than its distal branch. The root in its direction follows the corresponding part of the crown. This arrangement of the root is illustrated in figure 325, *b*. *Sinanthropus* (fig. 325, *a*) shows *mutatis mutandis* exactly the same position of the roots. In my earlier paper referred to above (1934) I was able to show that the special position of this mesiobuccal branch of the root apparently is a consequence of its close connection with the alveolus of the upper canine. There is only a very thin septum separating the openings of the corresponding sockets. The big root of the canine, however, forces the buccal wall of the socket to strongly bulge over the lateral surface of the maxilla and includes the mesiobuccal branch of the premolar root which adjoins closely. I gave a photograph illustrating these conditions in my publication quoted above as figure 63 (p. 82) pertaining to the alveolar of a male orang. Hence, I arrived at the conclusion that the basal prominence of the first upper premolar is really caused by a large upper canine and its persistence in *Sinanthropus* (and recent man) therefore must be considered to be an indication of there formerly having existed a still larger one.

It seems to me that another peculiarity very distinct in *Sinanthropus* points in the same direction. As Diagram 2 shows P^1 is considerably more robust than P^2 and even bigger than C^1 and the same holds good for some races of recent man (Diagr. 3). In chimpanzee (Diagr. 40) P^1 and P^2 are of about the same robustness and P^1 is of course much weaker than C^1. In female gorilla (Diagr. 42) P^1 is larger than P^2, whereas in female orang (Diagr. 44) the difference is not so great. Such an extraordinary development of P^1 as in *Sinanthropus* and its exceeding even C^1 can only be understood by supposing the pre-existence of a bigger canine and a stronger reduction of the latter as actually proven by the figures given above.

The appearance of the canines and premolars of *Sinanthropus* shed new light on the canine problem of hominids which are discussed so frequently. The upper canine must have been considerably larger and higher and, already in the *Sinanthropus* stage of evolution, it must have undergone a remarkable reduction. The upper canine undoubtedly projected beyond the level of the chewing surface overlapping the buccal sides of the lower canine and the first lower premolar but it did not interlock between these teeth. Furthermore, there exists an important difference between the upper and the lower canines. While the upper one reveals a typical canine pattern, the lower canine approaches more the incisor type. The first lower premolar has never been of a pronounced sectorial type but it was always more molariform with a buccal and lingual main cusp and a distinct talonid. All these features have to be considered as primitive primate characters which were also fundamental for living anthropoids. Yet in contrast to the hominids the latter have been specialized, the gorilla and orang more and the chimpanzee less and the males of all three families again more than the females. But besides their specific "canine" form and the sectorial shape of the first lower premolar the canines as well as the first and second premolars of the anthropoids show in all other details the same characteristics as *Sinanthropus*. This fact proves that in spite of that differentiation *Sinanthropus* (hominids) and the anthropoids have to be considered as members of one and the same primate group.

4. MOLARS

Like the canines and premolars the molars of *Sinanthropus* exhibit a special characted. They have in common a very well formed cingulum and the presence of accessory ridges, the development of which has reached the highest degree here. As is true of all primates there is a great difference between the upper and lower molars. While in the upper molars the general similarities to the anthropoid molar overshadow the minor differences between them, especially in cases of worn teeth, the lower molar appear to be much more distinct and specifis.

In the following description of molars the first and second will be treated jointly, while the third one will be dealt with separately because of the closer affinity of the first two mentioned. Another reason is that our material is composed of many isolated first and second molars of which the assignment to their respective positions within the denture is rather difficult.

Questions relating to all molars, the significance of "wrinkles" and the so-called taurodontism will be discussed below.

a. UPPER MOLARS

The first and second molars (figs. 109, 110, 111, 113, 114, 119, 120, 122, 127, 275-278, 330, 345)

Our material of first and second molars is composed of fifteen teeth consisting of eight isolated specimens and seven embedded within their respective sockets of the upper jaw fragments, thus making possible an accurate determination as well as a reconstruction of the missing part of the maxilla, including the teeth (figs. 127, 277, 345). In addition, it was possible to define the isolated teeth as either representing the first or the second molar.

It is quite probable that the germs without roots represent second molars, for all fragments of skulls or mandibles hitherto found in Locality I belong to individuals with the first molar already erupted or just erupting. Therefore, the recovery of germs of a first molar would indicate the presence of very young individuals, a condition which has not been confirmed by other remains. Possibly, germ No. 140′ may represent a first molar because it was found together with the but slightly worn second milk molar (No. 139′). The uncertainty connected with the diagnosis is of some importance only when determining the difference in the size between first and second molar but rather irrelevant as far as the general shape and the special pattern of the chewing surface are concerned, since we know that neither in anthropoids nor in recent man essential differences exist between the two molar types in this respect.

Three of the 15 teeth available are germs and entirely intact, whereas the other are more or less worn. Two of the latter are so badly damaged as to render them unfit for description. As to the sex three molars belong to male individuals (large type) and twelve to female (small type).

The crowns of the first and second molars are considerably broader than long. They display, when viewed from the chewing surface, a usually rectangular form with the buccal corners somewhat more angular and the lingual ones more rounded off (figs. 109, *o*; 113, *o*) but occasionally also the reverse conditions may occur (fig. 330, *o*). In some cases the rectangle is replaced by a more rhomboid figure with the paracone (fig. 109) projecting strongly in mesial and buccal directions. The four cusps are well developed (figs. 113, *b*, *l*; 114, *b*, *l*; 330), both mesial cusps (paracone and protocone) being slightly higher than the distal ones (metacone and hypocone). The rhomboid shape partly also depends upon the direction in which the cusps leave their base. While the metacone and the hypocone rise in more or less erect position, the metacone and more in particular the paracone bend inward (fig. 330, *m*, *o*). The buccal surface reveals in most of the cases (figs. 113, 114, 119) a very characteristic relief, the outside of the paracone and occasionally also that of the metacone (fig. 119, *b*) bearing a moon-shaped ridge demarkating the central part of the cusp from the surface proper. This formation apparently must be taken to be as a clear indication of a cingulum beyond which the cusps rise more or less like isolated peaks.

The mesial surface (figs. 113; 114, *m*; 330) shows a very characteristic feature, the rim leading from the paracone to the protocone being distinctly crenated. This crenation continues into the lingual surface of the protocone in such a way that the latter appears to be covered with a very faint striation.

The most conspicuous feature is the pattern of the chewing surface. In cases where the molars are worn it is not possible to recognize more than the presence of four cusps, their aproximate size and some furrows separating them from each other. Molars which are intact, however, reveal an entirely different aspect. In the cases given in figures 113, 114, 330, the chewing surface proper represents a real angular area the greater axis of which is orientated in the longitudinal direction. This area is bordered by the tips of the cusps and the edges which connect them. Only in the region of the hypocone this arrangement is somewhat disturbed (fig. 113, o). Thus a buccal and a lingual edge may be distinguished each of which embraces the two corresponding buccal and lingual cusps respectively, and, furthermore, a mesial and a distal edge uniting the buccal with the lingual ones on the corresponding sides. All these edges correspond to the "main ridges" ("Hauptleisten") of Remane (1927). The paracone is separated from the metacone by a deep transversal furrow which transgresses the buccal edge and descends to the buccal surface. A second, shorter and obliquely directed furrow separates the hypocone from the metacone, the protocone continuing into the lingual surface. Real longitudinal furrows are lacking. Instead of the latter there is a V-shaped groove in the mesial moiety demarkating a triangular field the base of which is formed by the mesial edge crowning the mesial wall, with its apex coming near to the center of the transversal furrow where the paracone and the protocone meet. The distal moiety of the surface fails to exhibit a longitudinal furrow and is replaced here by a relatively broad depression beginning at the center just mentioned and extending to the oblique furrow separating the hypocone.

Apart from this general appearance, however, the pattern of the chewing surface is complicated by the special configuration of the slopes descending from the bordering main ridges and tips of the cusps, respectively. In the mesial moiety the slope of the paracone limited by the buccal half of the above mentioned V-shaped furrow on its mesial side and the buccal half of the transversal furrow on its distal side consists of three indistinct wrinkles. The slope of the protocone shows a larger middle wrinkle and a smaller one on either side. The triangular field intercalated between the two slopes represents also a kind of slope descending from the mesial main ridge and also shows several irregular wrinkles. The slope of the metacone appears to be still more complicated. It is composed of irregular wrinkles and seems to continue beyond the longitudinal midline within a distal portion of the slope of the protocone. This portion gives the impression of being a small accessory cusp separated entirely from the protocone but connected with the metacone. The lingual view of the crown (fig. 113, *l*) shows that there indeed are two indents separating a special rounded portion of the edge from the protocone as well as from the hypocone. The surface of the distal section of the protocone like all the other slopes is covered by irregular wrinkles. With respect to the hypocone differentiation should be made between the hypocone occupying the distolingual corner of the crown and the adjacent small ridge which forms the distal edge of the surface and joins the metacone. Of wrinkles there is only a small one where the hypocone continues into the distal edge.

As to the size of the cusps the exact estimation is hard on account of the difficulty to determine their actual boundaries. The protocone seems to be the largest cusp followed by the metacone, then the paracone and finally the hypocone.

The upper molar illustrated in figure 114, *l*, exhibits a somewhat different pattern of the chewing surface (*o*). The whole crown is more rounded and the scheme of the pattern itself is not so definite as in the preceding case. Nevertheless, the pattern type is the same in principle as is revealed by a detailed comparison. The cusps are of the same height as in that case. The division between the two mesial and distal cusps by the transverse and oblique furrows is clearly indicated on the buccal and lingual surfaces (fig. 114, *b*, *l*). The transversal furrow, however, is rather indistinct on the chewing surface, while the oblique furrow separating the hypocone from the protocone and metacone, respectively, is rather well pronounced. With respect to other details the arrangement of the three areas of the mesial moiety, namely the triangular field bordered by the V-shaped fissure and the slopes of the paracone and protocone with their relevant wrinkles is about the same as in figure 114, *o*. The above described distal portion of the protocone, however, which is in connection with the metacone seems in this case to be reduced to a mere wrinkle of the protocone severed from it by the interlocking lingual end of the metacone slope. The hypocone is small and its slope consists of two to three wrinkles; the distal main ridge however is broad and well developed and also shows some faint indications of folds.

In the case of the molar illustrated in figure 330 the pattern of the chewing surface in principle is about the same as in the two cases just described as far as size, abundance and arrangement of the wrinkless are concerned. Nevertheless, some differences may be observed. The most interesting of them is the way in which protocone and metacone are connected with each other. A small distal section of the former widening downward is partly separated by a fine cleft which appears as the direct lingual continuation of the transversal furrow between paracone and metacone. This protocone section meets with a rather similar formation of the metacone, a fine but very superficial cleft separating both ridges. The V-shaped furrow of the mesial moiety is not as distinct as in the two first described molars but on the other hand the wrinkles of the mesial and distal bordering edges of the surface are pronounced. Those of the former edge continue beyond the rim into the crenation of the mesial surface mentioned above.

Such original patterns bring about a better understanding of the arrangement of the furrows and limits of the cusps when worn teeth such as those of figures 109, *o*; 119, *o*; 120, *o*; 127, M^2; 276 and 277 are taken into consideration. In the first five cases the transversal fissure and its continuation to the buccal surface is preserved and also the buccal half of the V-shaped fissure, whereas the lingual side is less distinct. The oblique fissure is well preserved in two instances. In figures 119 and 276 the direct connection of the metacone with the distal portion of the paracone is clear; but in figure 120 there is a fine cleft separating the cusps. Figures 110, *o*, gives the impression as if a regular cross pattern had existed with the hypocone of the same size as the other cusps. The pattern of figure 276 is almost identical with that of figure 330. Since the real nature of the pattern may only be understood after a comparison with the molars of anthropoids, this question will be dealt with below.

The root of the two first upper molars consists of three separated branches (figs. 109, 110, 111) which, however, show a tendency toward fusion (figs. 119, 120, 122). Whether this tendency is restricted to the second molar or whether it is also true of the first one is impossible to decide on account of lack of suitable and accurately determined material. In the case of the upper jaw of Skull I Locus L (figs. 127 and 277) the root of M^1 consists of three separated branches, while that of M^2 is partly fused (figs. 120, 122). In all cases regardless whether the root is divided or fused there is an undivided stem of a certain height, a phenomenon which will be discussed in connection with the same feature of the lower molars. In divided roots there are two buccal and one lingual branch (figs. 109, 110, 111). The former are close together and developed more in transversal direction, while the latter diverges at a rather wide angle from the buccal branches and is orientated in longitudinal direction (fig. 110). Of the two buccal branches the mesial one is broader and projects together with the corresponding cusp of the crown (paracone) far toward the buccal surface. Whenever the branches are fused there is only a slight divergence of the lingual branch, the latter being especially fused with the mesial portion of the buccal branches (figs. 120, *m*; 122) whereas the distal portion retains a greater degree of independence. As to the height and shape of the branches, the one diverging is always the longest; it is oval in cross section and may show a shallow longitudinal depression on its lingual surface. The two buccal branches are oblong in cross section and compressed in mesiodistal direction. In the case illustrated in figure 120 the apices of the distobuccal and the lingual branches are sharply bent distalward. The crown rest upon the root in such a way that its mesial and distal surfaces project more than the buccal and lingual ones. A real constriction does not exist, but just above the neck there is a small basal, ring-like elevation around the whole crown which is more pronounced on the buccal and lingual surfaces than on the mesial and distal ones (figs. 109, 120).

TABLE XVI

Measurements of upper molars of *Sinanthropus*

a. First molars determined *in situ* and those recognized with a reasonable degree of certainty

		No. 31 ♂	271. No. 32 ♀	109:110 No. 33 ♂	213 No. *94* ♀	111:121 277 No. 95 ♀ cf. 305	330 No. 140 ♀	No. *144'* ♀
crown	height	—	8.3	(6.8)	(5.9)	(6.0)	7.5	(5.3)
	length	13.1	11.3	12.1	10.0	10.2	11.1	10.6
	breadth	—	11.7	13.4	11.7	12.3	13.7	12.4
root	height	—	—	15.4	b 15.4	l 13.7	—	b {m 12.7 b {d 13.0 l 14.2
	length	—	8.2	8.9	8.4	8.1	—	8.0
	breadth	—	11.3	13.2	11.3	11.6	—	12.1

[illegible]: 11,7
[illegible]: 12,

b. Second molars determined *in situ* and those recognized with a reasonable degree of certainty

		No. 39 ♀	114:278 No. 40 ♀	113:275 No. 41 ♀	119 No. 42 ♀	160 313 No. *104* ♀	122:155 277 No. *105* ♀ cf. 308	No. *145'* ♀
crown	height	(5.7)	(5.6)	8.2	(7.2)	(5.8)	(6.2)	(6.4)
	length	10.5	12.2	11.1	11.4	10.3	10.2	10.6
	breadth	12.3	12.2	13.2	12.4	12.8	12.8	13.4
root	height	l 15.2	—	—	b 17.7	l 15.1	13.5	b 13.0 l 14.2
	length	7.8	—	—	7.9	8.4	8.9	7.3
	breadth	12.6	—	—	11.7	12.4	12.8	11.3

[illegible]: 10,9
[illegible]: 11,7

Instead of following the procedure of description adopted above, a comparison of the upper molars of *Sinanthropus* and those of anthropoids will be made first because of their close resemblances. Figures 117, 118, 298 and 331 represent the first and second molars of gorilla. As figure 117 shows the rhomboid character with the paracone protruding toward the buccal side and the protocone bending buccalwards is rather pronounced in this case, whereas in that illustrated in figure 298 the first molars are rectangular, while the second molar is distinctly rhomboid. The orang and occasionally also the chimpanzee exhibit the same feature. The oblique shape of the anthropoid molars due to the protrusion of the paracone and the bending of the protocone both in buccal direction is usually less pronounced in the first molar, more so in the second and still more in the third one. In gorilla the base of the molar is formed by a cingulum which surrounds the whole tooth, except the hypocone (figs. 117, 118, 331). Above this cingular base the paracone, metacone and protocone rise as isolated cusps, whereas the hypocone merely appears as a pointed elevation of the cingulum itself (figs. 117, 331). The distal main ridge descending from the tip of the hypocone bends lingualward and continues into the distal edge, thereby forming the distal border of the tooth, or in other words, this distal edge is a part of the cingulum itself which in its further course embraces the metacone.

Similar conditions exist on the mesial border of the tooth, the edge representing merely the corresponding part of the cingulum. On the lingual surface the cingulum is very strongly developed at the base of the protocone (figs. 117, 331), the same is also true occasionally of the buccal surface. Here it appears as an arcade which confines the base of the more or less isolated cone-like cusps and rises toward the mesial and distal edges and to a higher level in the former than in the latter (fig. 118).

With respect to the general shape the molars of *Sinanthropus* do not differ distinctly from those of the anthropoids. The cingulum is reduced, it is true, to a general basal swelling of the crown described above, but on the buccal surface it sometimes is well preserved and represented by the half moon-shaped arcades embracing the base of the paracone and metacone (compare figs. 119, *b* with 118). Moreover, there is no doubt that the two folds which border the buccal surface of the paracone (figs. 113 and 114, *b*) correspond completely to the ascending section of the cingulum (fig. 118). More than this, the distal fold which runs near the deep furrow separating the paracone from the metacone appears to be a direct remainder of a stylar cusp (mesostyle) so characteristically developed in the upper molars of *Notharctus* (compare Gregory 1922, Plate 7, fig. 4).

As an example for illustrating the pattern of the chewing surface a first molar of gorilla was chosen (fig. 117) because of the latter's great distinctness in the general arrangement of the cusps and their connections. Instead of the quadrangular form circumscribing that surface proper there exists here a triangular one, the trigon, the tip of the protocone being in direct connection with the tip of the metacone by a sharp and well developed crista obliqua. On the mesial side the border of the trigon is formed by the mesial marginal edge which connects the paracone with the protocone by way of their main ridges. Distally from this marginal edge and separated from it by a deep groove there is a second connection between the two above mentioned cusps apparently formed by ridges of accessory nature which descend from the cusps themselves. I consider the mesial marginal edge as equivalent to the crista transversa of the trigon. For in the first molar of a gorilla child just erupting (illustrated in fig. 331) the conditions in question may be clearly seen. The cingulum descending here from the tip of the hypocone surrounds the base of the protocone and then ascends again to the mesial marginal edge. Just at the point where it merges with the latter it meets with the main ridge descending from the tip of the protocone and again at this point a very minute wrinkle starts in the direction to the middle ridge of the paracone. On the buccal side the mesial marginal edge continues directly into the main ridge, descending mesialward from the tip of the paracone. These conditions correspond perfectly to those existing in *Adapis magnus* (cf. Gregory, 1922, fig. 66, p. 136) with the exception of that minute protocone wrinkle. A distal ridge descending from the hypocone continues directly into the distal marginal edge, while the buccal section of the slope of the hypocone bearing certain wrinkles meets with a corresponding distolingual section of the metacone (fig. 117). However, these sections remain separated by fine clefts. Such a cleft divides also the crista obliqua whereas the slopes of the para- and metacones are separated by a more pronounced furrow. The gorilla molar pattern is characterized further by well developed high and pointed cusps the slopes of which are covered by distinct wrinkles, though finer and not as abundant as in the case of *Sinanthropus*.

As to the orang (figs. 125, 332, 336, *a*) the general arrangement of the cusps is the same as in gorilla but there are great differences in certain details. In this respect it does not matter that the orang molar illustrated in figure 125 is a second one and that of the gorilla (figs. 117, 331) a first one. The cusps of the former are much lower and blunt and the entire chewing surface proper is densely covered with accessory ridges descending directly from the tip of the cusps and the adjoining main ridges or deviating from the larger accessory ridges themselves. This complication of the pattern apparently is the cause of the conspicuous indistinctness of the crista obliqua in the case of figure 125, which is represented only by the oblique direction of the metacone slope and its meeting with a distal and slightly separated part of the protocone slope. A fine cleft separates the two slopes. The area of the crista transversa in orang is also occupied by a mesial marginal edge and a large irregular accessory ridge the special arrangement of which is due to individual variation. The hypocone is isolated by an oblique furrow and the wrinkles of its slope meet with those of the metacone but a directly connecting ridge does not exist. It is of great significance that the pattern of the molars of the fossil orang (figs. 126, 332, 336) is the same as in recent orang. The two types, however, differ in the distinctiveness of the cusps and the degree of the development of the wrinkles. The cusps are clearly higher and more pointed in the fossil type than in the recent one. Apparently in accordance therewith the wrinkles are coarser and less abundant in the former than in the latter. Slightly worn molars of fossil orang may occasionally exhibit therefore a pattern of the chewing surface surprisingly similar to that of *Sinanthropus* as is evident by a comparison of figure 332 and figure 330, the former being recognizable as representing and orang only by the doubling of the crista transversa.

Gregory (1922) described the molar pattern of *Dryopithecus* and compared it with that of the Mousterian youth, basing his descriptions on worn teeth only. However, when taking the only intact germ of *Dryopithecus* (*Dryopithecus germanicus* of Melchingen, fig. 116) as an example, the result of such a comparison will be different. This *Dryopithecus* molar shows the same pattern in principle as the gorilla molar, the differences being in that the cusps are lower and less pointed, but on the other hand the winkles are much better developed. In addition the *Dryopithecus* molar shows a distinct direct connection between the metacone and hypocone.

As a whole, however, the *Dryopithecus* problem seems to be rather complicated because of the great variation which the molars attributed to this fossil anthropoid reveal. As in most of the other cases nothing else but a single isolated tooth is preserved, it is impossible to ascertain whether we are in all cases actually dealing with the same genus or with very different ones. I am, of course, not in a position to discuss this problem here and. therefore, refer to the publications by Gregory (1922) and O. Abel (1931). For instance, the upper molar described by Glæssner (1931 and attributed to *Dryopithecus darwini* Abel (fig. 335) differs not inconsiderably from the molar of *Dryopithecus germanicus* just described (fig. 116) and designated as *Dryopithecus rhenanus* by that author. Although this tooth is worn the original pattern is very well preserved in some sections and bears indications of wrinkles which in the degree of their development resemble more those of chimpanzee than those of gorilla. The connection between hypocone and metacone is lacking and the crista obliqua is interrupted by a deep fissure.

I refrained from describing the pattern of the chimpanzee because of its general conformity to that of gorilla, orang and *Dryopithecus*. Major differences involve merely the development of the cusps and the wrinkles. With respect to the cusps they are not so pronounced as in gorilla while the wrinkles are more distinct and abundant than in the latter. In both these features chimpanzee approaches *Dryopithecus* and fossil orang very closely.

When comparing the molar pattern of *Dryopithecus germanicus* (fig. 116) and gorilla (fig. 117) with that of *Sinanthropus* it becomes apparent that there are differences and not so unimportant at that. Size, height and position of the cusps of the *Sinanthropus* molar are about the same as in *Dryopithecus* and gorilla and the same is true of the size and abundance of the wrinkles, but in other details the *Sinanthropus* molar differs from that of the two type. Firstly, the mesial trigon crest uniting the paracone and protocone (crista transversa) is represented in *Sinanthropus* only by the mesial edge while the second connection more distally located in those apes is entirely lacking in *Sinanthropus*. In its place there is a triangular field bordered by the V-shaped furrow and covered by special wrinkles as has been described above. Secondly, the crista obliqua so sharp and well pronounced in *Dryopithecus* and gorilla presents a different aspect in *Sinanthropus* by being only a low, indistinct and wrinkled bridge leading from the tip of the metacone not directly toward that of the protocone as in the former types but rather toward an accessory cusp which appears more or less as a separated distal portion of the protocone (figs. 113 and 114, *o*). Thirdly, the ridge connecting the hypocone with the metacone, very distinct in *Dryopithecus* (fig. 116) and faintly indicated in gorilla (fig. 117) is completely absent in *Sinanthropus*. With respect to these three points, however, *Dryopithecus darwini* (fig. 335, see above) approaches *Sinanthropus* much more than *Dryopithecus germanicus*. The crista transversa, it is true, consists here also only of one trend represented by the mesial edge but the special triangular field distally from the latter and peculiar to *Sinanthropus* is lacking. Furthermore, the crista obliqua is well developed and the manner of its course does not differ essentially from that of *Dryopithecus germanicus* and gorilla but the deep fissure separating its buccal and lingual portions resembles more the conditions in *Sinanthropus*. The orang (figs. 125, 126, 332), fossil as well as recent, approaches *Dryopithecus* with respect to the first point, while in regard to the second and third one it comes closer to *Sinanthropus*.

It is surprising that with regard to the protocone-metacone connection the first upper molar of *Australopithecus* (Dart) exhibits exactly the same conditions as *Sinanthropus* and thereby differs, together with the latter, from *Dryopithecus*. gorilla and orang. W. Able (1931) was first to call attention to the fact that in *Australopithecus* the crista obliqua does not deviate from the tip of the protocone but from a distal accessory cusp separated from that cone. Adloff (1932) mentions, it is true, this feature also but does not attach any importance to it. Finally, Dart (1934) described the connection between the protocone and metacone as a low bridge and not as a true ridge omitting, however, any reference to the specific manner of its connection with the protocone. As figure 115, a sketch of the cast and photographs of this *Australopithecus* molar show, the accessory cusp distally from the protocone is identical with the corresponding cusp of *Sinanthropus* (fig. 113, *o*): in both cases there are typical transversal and oblique furrows separating the metacone together with the lingual accessory cusp from the paracone and protocone on the mesial side and from the hypocone and the distal marginal edge on the distal one.

Moreover, the metacone and the accessory cusp of *Australopithecus* like all other cusps are covered by typical wrinkles of a coarser type and, hence, less abundant than in the case of *Sinanthropus* but nevertheless very distinctly developed. Furthermore, the low bridge linking the accessory cusp with the metacone is interrupted by a fine longitudinal cleft in exactly the same manner as in *Sinanthropus* and in fossil and recent orang. Finally, the hypocone is well developed and completely separated from the metacone by the oblique furrow described above, it continues directly into the distal marginal wall. On the other hand the differences in the molar pattern between *Australopithecus* and *Sinanthropus* concern only the configuration of the crista transversa which in *Australopithecus* consists of two ridges very close together, separated merely by a short and fine groove. This feature bears a close similarity to the one of *Dryopithecus* and fossil orang (fig. 332) but is different from that of *Sinanthropus*.

With respect to the general shape of the *Australopithecus* crown it is evident that its mesial part is narrower than its distal one or, in other words, the paracone does not protrude in mesiobuccal direction and the outline of the crown therefore approaches more a quadrangular rather than a rhomboid figure. However, this peculiarity may also occur in first molars of anthropoids (fig. 298) and is likewise recognizable in the *Sinanthropus* molar given in figure 114. Unfortunately, I was unable to ascertain whether a cingulum surrounds the crown of the *Australopithecus* molar or whether it is absent. It is not mentioned in the available literature. Dart (1934) failed to make any reference to it in his publication but, according to Adloff (1932), Dart confirmed the existence of a genuine buccal cingulum at the corner of the paracone by letter. Such a location would correspond to the feature of *Sinanthropus* described above.

Taking all the peculiarities described into consideration there cannot be the slightest doubt that *Sinanthropus* belongs to the same primate group as the anthropoids, including *Dryopithecus* and *Australopithecus*. Such essential features as those defining the character of the upper molars are the same in all these types and stand in contrast to those of other primates. However, within that large group of anthropoids some genera show certain differences which do not have to be reported on here as far as the recent anthropoids are concerned. Such differences as exist, however, become of importance when the question of the closer relationship between the members of the whole group arises.

The fact that *Dryopithecus* must be excluded from having direct relationship to hominids has already been proven by a comparison of the lower canines and first premolars. In the case of the molars the connection between hypocone and metacone which must be considered as a later differentiation and one which is completely absent in *Sinanthropus* may also serve to further support such a rejection unless one admits the possibility of a secondary new reduction which seems to have taken place in gorilla. It must be borne in mind, however, that this consideration does not apply to *Dryopithecus darwini*; unfortunately, the canines and lower premolars of this genus are unknown (see below). Indeed, Bolk (1914) in discussing the same problem with regard Siamang and *Semnopithecus* considers the hypocone-metacone bridge of *Dryopithecus* as a special differentiation and very different from the corresponding appearance in recent man. The second difference between *Dryopithecus* and *Sinanthropus* concerns the special configuration of the crista transversa. *Dryopithecus* as also *Australopithecus* and all recent anthropoids including the fossil orang show the same feature in this respect, while *Sinanthropus* and the other hominids differ from them. I restrict myself to this statement without going into details as to its significance to the problem in question.

The first and second molars of recent man (figs. 112 and 121) offer quite a different aspect when compared with those of *Sinanthropus*. Like in the other teeth the crown is much smaller in the mesiodistal and buccolingual diameters, especially in the former, while the height is about the same. If all four cusps are well developed then there is no difference in the shape of the crown. There is a distinct tendency in recent man, however, to enlarge the protocone at the expense of the paracone, the metacone and especially also of the hypocone. The latter appears of being gradually absorbed by the protocone, a process which becomes more intense from the first to the third molar so that finally one cusp remains on the lingual side and the originally rhomboid angular tooth has been transformed into a triangular one (compare figs. *112, o* and *121, o*). The enlargement of the protocone takes place not only in distal direction but also in a buccal one as revealed by the asymmetrical position of the longitudinal furrow or its equivalent. In *Sinanthropus* the boundary between the slopes of the protocone and paracone coincides with the midline of the crown, while in recent man it has shifted, after Lenhossek (1922), toward the buccal side, that is to say, the space occupied by the protocone has increased at the expense of the two buccal cusps. According to Hildebrand (1908) the tricuspid type occurs only in 0.2% in the first molar but in 38% in the second. Lenhossek (1922) and de Terra (1908) even give higher values: 53.2% and 57.3%, respectively, for the latter. Whether or not such a tendency had already been established in *Sinanthropus*, I am unable to judge due to lack of sufficient numbers of first and second molars.

As to the special features, a cingulum and its derivatives are completely absent on the buccal surface but they are occasionally present in the same way as in *Sinanthropus* on the lingual surface of the protocone where they may cause the formation of an accessory cusp-like protuberance, the so-called Carabelli tubercle, which however, has not been found hitherto in *Sinanthropus*. I shall return to this question later.

The chewing surface is smooth: the main ridges and cusps are rounded and accessory ridge are entirely lacking. The crista obliqua is reduced to a faint swelling deviating from the slope of the protocone. However, this simple pattern which Lenhossek regards as typical for recent man (compare his figures 112 and 121) shows very great variations. In the Chinese material at our disposal there are molars which exhibit a rather complicated pattern resembling that of *Sinanthropus* in a moderate form and the same is true for the unworn or slightly worn molars of Australian Aboriginals. There exist pointed cusps, sharp ridges, distinct furrows and also some wrinkles, although much less abundant and distinct than in *Sinanthropus*.

The roots show the same effect of reduction as the crown. Their undivided portions are low and constricted in both dimensions. The single branches are weak and slender and curve toward each other. The lingual branch does not spread as straight and as far away from the buccal one as in *Sinanthropus*; thus the angle formed by the branches is not as wide and acute as in the latter.

The molars of the Neanderthal group (figs. 123 and 124) are closer to recent man than to *Sinanthropus*. It is true, the hypocone even of the second molar is, as illustrated by the molar of Le Moustier (fig. 124), still developed but the metacone appears to be already somewhat reduced so that the originally quadrangular form has been partly lost. In the case of the Mousterian youth also a slight reduction of the mesiodistal diameter of the crown has taken place. The general arrangement of the cusps is the same as in *Sinanthropus*, but even in unworn specimens the cusps themselves and the main ridges are rounded off and the pattern is not in any way as distinct as is characteristic for the former, and in addition, it only shows a limited number of wrinkles. The crista obliqua is indicated in the cases of Krapina (fig. 123) and Le Moustier (fig. 124) whereas the crista transversa is less distinct. In the Krapina molar a trace of the V-shaped furrow on the mesial side of the paracone and protocone is still recognizable. On the mesial lingual corner of the protocone there is a triangular pit separating the corner itself from the main part of the protocone (fig. 123). Gorjanovic-Kramberger (1906) considered this separated portion as a representative of the carabelli tubercle (see below).

With regard to the root, most of those of Krapina molars are, according to Gorjanovic-Kramberger (1906), fused in a special manner which will be discussed below. The roots of the Mousterian youth are only briefly mentioned by Gregory (1922) who compared them with the roots of anthropoids; the buccal branches are straighter and less divergent than in the anthropoids. The roots of La Quina molars are described and illustrated by H. Martin (1923). They closely approach those of *Sinanthropus* in respect to robustness (fig. 333). It is worth noting, however, that the lingual root deviates distinctly less than that of *Sinanthropus* (figs. 109, 111) and is not straight but slightly curved toward the buccal branches and thus represents with this detail also an interesting intermediate stage between *Sinanthropus* and recent man.

First and second upper molars of *Sinanthropus* display the same appearances as the other types of teeth described above. They approach very closely to those of the anthropoid group, although they differ from them in certain particular details. However, their pattern is not definitely fixed but shows a relatively wide range of variation. The wrinkles are a very characteristic feature of this pattern. The molars of recent man represent in their common form only a faint copy of the original type; they are strongly reduced in size, the proportion of their crown has become changed and the pattern of their chewing surface considerably simplified. The relation to the original type is manifest not only by certain variations occurring in different races of present day man but also by the appearance of the corresponding molars of the Neanderthal group which, although as a whole resemble more those of recent man than those of *Sinanthropus*, reveal peculiar features similar to those of the latter, so that a distinct line leading from *Sinanthropus* up to recent man can be traced.

Third molar (figs. 127-130, 135, 136, 277, 279-282, 345)

Our material of third upper molars is composed of seven teeth consisting of four isolated and three found together with the jaws. The accurate determination even of the isolated teeth is comparatively easy because of the very characteristic feature of the third molar. The chewing surface of one of the isolated teeth (fig. 128) is completely preserved; this tooth apparently represents a very young germ with the lower part of the crown not fully developed. The remaining molars are more or less worn but nevertheless reveal characteristic features which permit a satisfactory criterion of their typical appearance. According to their size all molars belong to female individuals; the largest one (figs. 127, 135) are those found with the jaw which belongs to the female Skull II Locus L.

The available *Sinanthropus* material of third molars does not show any special irregularities besides those common to the first and second molars; the general appearance of the crown in particular does not differ remarkably from that of the first and second molars as far as its proportions and the features of the four outer surfaces are concerned. In the case illustrated in figure 135 the buccal surface exhibits a characteristic trace of the cingulum which is faintly indicated also in figures 128 and 136. The most striking peculiarity of the molar, however, is the smallness of the metacone which is reduced in length and in breadth to the same extent, and, in some cases, even inferior to the hypocone. In consequence thereof the paracone protrudes strongly buccalwards the distal part of the contour of the buccal surface receding in the same degree, so that the outline of the molar approximates a triangular one with the base on the mesial side and the angles rounded off. In regard to the size of the paracone and protocone, the latter appears to be the larger one as is true in the preceding molars. There also is a bridge-like connection between the protocone and metacone, although this bridge is interrupted by a distinct furrow running within the longitudinal axis of the tooth. In figures 128 and 135 the protocone portion of this bridge is formed by a coarse wrinkle distinctly separated from the protocone proper by a deep transversal furrow and deviates from the distal main ridge descending from that cusp. These cases bear a remarkable resemblance to that described above as peculiar to *Sinanthropus* and illustrated by figures 113, *o*, and 114, *o*. All four cusps are present. The size of the hypocone, it is true, varies but nevertheless is well developed, with the exception of the case given in figure 128. In the molars of figures 135 and 136 the hypocone is separated from the protocone by a distinct indentation on the lingual side.

As to the special pattern of the chewing surface the real structure is not as easily defined as was true in the first and second molars because of lack of suitable unworn tooth specimens. However, the material available suffices for the determination of the main features and also permits the statement that there are no essential differences between this and the other molars. It is of special interest to note that the crista transversa here is also represented by the mesial edge which forms the basis of the triangular field intercalated between the slopes of the paracone and metacone and is covered by numerous small wrinkles (figs. 128, 129, 130, *o*; 279). The distal edge continuing into the hypocone is likewise well developed and distinctly crenated because of the presence of certain wrinkles of the chewing surface which form notches in the edge itself (figs. 135, 136, *o*). The fact that the slopes of the cusps have been also covered by such accessory ridges may be inferred from the abundance of fine furrows deviating from the main ones (compare the photographs: figs. 280 and 281).

One feature is of special interest. In figure 129 (280) the worn chewing surface of the protocone shows a fine interrupted and irregular linear groove which courses arch-like parallel and close to the lingual surface. This groove comes nearer to the surface toward the mesial side than toward the distal one, that is to say, it ascends from the distal towards the mesial corner of the protocone. I consider the groove or more correctly the basal part of the buccal surface of the protocone bounded by it to be a relic of the cingulum and will refer to this feature below.

The roots are complete in five molars with three belonging to various individuals. In one case the inferior end is broken off but the arrangement of the branches may still be seen. In the two molars which belong to the same individual (female Skull II Locus L) three separated branches (fig. 135) are present the general arrangement of which is the one characteristic for upper molars, with the mesiobuccal branch projecting in buccal direction. However, there is a clear tendency toward fusion inasmuch as the lingual branch does not deviate as strongly from the buccal one as in the first molars illustrated in figures 109 and 111; in addition the lingual branch is partly connected with the mesiobuccal one by a high and thin sheath of root substance as is seen in figure 120 also. In the case given in figure 130 (279) the degree of fusion is more advanced in that the lingual and mesiobuccal branches bend toward each other and the distobuccal one intercalates between the two (*d*). In figure 136, finally, there exists only a single undivided, low and stout root, particularly developed in buccolingual direction the original tripartite character of which is still recognizable by a deep furrow on the distal side (*d*) and a faint longitudinal impression on the buccal one (*b*). The root fragment of the molar of figure 129 exhibits the same character as that of figure 136 but the fusion here is not so advanced and somewhat different in that the distobuccal branch leans against the distal sides of the mesiobuccal as well as the lingual branches. In all cases, regardless whether the root is fused or not, the roots are bent or inclined distally. As to the manner of connection between crown and root it is obvious that the constriction of the neck region is less pronounced in cases with strongly fused roots than in the other and that in the latter the crown projects considerably over the mesial and distal sides but much less on the buccal and lingual ones.

In addition to these *Sinanthropus* third molars there is the hominid tooth of Choukoutien described by Zdansky (1927). As is apparent from figure 134, which was drawn on the basis of a good photograph and cast, this tooth is a typical *Sinanthropus* tooth. Its position within the molar series was left undetermined by Zdansky. It is a third upper molar of the right side. According to its size it probably belonged to a female individual. A comparison of this tooth, which is rather worn, with the other illustrated in figures 129; 130, *o*; 135, *o*; 136, *o* reveals no essential differences with the exception of the fact that the paracone in Zdansky's tooth is not so sharply separated from the metacone or the buccal surface as in other specimens. The metacone shows the diminution typical for the third molar; the bridge connecting this cusp with the protocone and interrupted by a fine furrow meets with a distinct distal portion of the latter. The root is single and, according to Zdansky, furrowed longitudinally in such a way that a fusion of the three branches is indicated. That author also called special attention to the facts that the mesiobuccal branch projects over the distal in buccal direction. As much as may be seen from the cast at my disposal it seems that the degree of fusion corresponds to one between those illustrated in figures 130 and 136.

It is very probable that the tooth collected by Haberer in Peiping and sent to Schlosser (1903) for study and description also belongs to *Sinanthropus*. That tooth also represents a left third upper molar and should thus be included here. The tooth is badly worn but nevertheles its general appearance resembles rather closely that of the *Sinanthropus* molars, especially the one given in figure 135, *o* with the result that I do not doubt their relationship to each other. Metacone and hypocone are well developed, the buccal branches of the root are fused in the upper parts and diverge toward the apices, the lingual one having been described as being "delicate."

TABLE XVII

Measurements of third upper molars

		130:279 294 No. 46 ♀	128:281 No. 47 ♀	129:270 No. 48 ♀	136 No. 49 ♀	135 242 No. *112* ♀	127:277 c/111, 305 No. *113* ♀	No. 146' ♀	134 Zdansky's molar† ♀	Haberer's molar
crown	height	(6.1)	—	(5.5)	(5.1)	(6.4)	(6.1)	(6.1)	(5.3)	—
	length	9.1	9.4	9.9	8.7	10.1	10.4	9.8	9.8	9.4*
	breadth	10.9	11.3	12.0	10.4	12.5	12.1	12.5	12.0	10.5*
root	height	*l* 16.5	—	—	*l* 10.3	*l* 16.3	*l* 16.3	*l* 14.2	*l* 16.0	—
		bm 14.5	—	—	—	*b* 15.0	*b* 15.0	*b* 13.0	—	—
		bd 12.5	—	—	—	—	—	—	—	—
	length	5.7	—	8.1	6.9	9.1	7.6	7.3	9.8	—
	breadth	10.8	—	11.2	10.3	11.4	11.8	11.3	12.0	—

† = measurements taken on the cast
* = after Schlosser

In its general appearance the third upper molar of the anthropoids closely resembles the first and second molars with one and rather important difference which is that in most of the cases it is considerably smaller. This smallness is not only a consequence of the general decrease in height, length and breadth, but also that of a special reduction of both distal cusps, the metacone and the hypocone. In the majority of cases the former is much more reduced than the latter. This reduction may even have reached such a proportion as to cause the entire cusp to be missing. In any case the contours of the molar become triangular with the base represented by the mesial side. Remane (1921) illustrated some of the cases in which a complete disappearance of the metacone or hypocone had taken place in chimpanzee, orang and gibbon. His belief, however, that such reduction of the cusps in question could never occur in gorilla must be erroneous, for the occurrence is clearly indicated in figure 298. This case is not at all an exceptional one, for in the male and female gorilla material at my disposal the reduction of the third molar is quite common and involves the metacone to a greater extent than the hypocone. The same is true in the fossil orang. Also in *Dryopithecus cautleyi** the reduction of the entire molar and the decrease of the metacone in particular is very distinct. As much as my material permits me to conclude the reduction of the molar may be confirmed by all primate groups including the prosimians, that is to say, that the third molar in many genera and individuals is smaller than the first and the second and an additional reduction has frequently taken place at the expense of the metacone. Only in Cercopithecinæ (macaques and baboons) the third molar may even be larger (longer and broader) than the second one. In the case of the fossil orang (fig. 282) the third molar is much smaller than the first or second (figs. 126, 332, 336), the metacone being particularly effected by the reduction. However, the arrangement of the main furrows and wrinkles remains unchanged.

The *pattern of the chewing surface of the anthropoid molars does not show peculiar alterations, with the* exception of those associated with the occurring diminutions and thus essentially concern a reduction of the crista obliqua.

As to the roots, according to Remane (1921) a fusion of the branches is frequent in gorilla, the distobuccal branch being in connection with the lingual one; the same is true for chimpanzee in which all three branches may be found to have fused and the same condition holds for the orang; in gibbon the third molar shows, according to that same author, a fusion of the three branches much more frequently and to a greater extent than that of the anthropoids. Zdansky's (1927) statement that all molars of the great apes possess three distinct branches is therefore incorrect.

In recent man (fig. 137) the third molar as mentioned above is an extraordinarily variable tooth. It is thus impossible to describe here all the variations that may occur. However, the majority shows a distinct diminution in the general size or one at the expense of the metacone, with the hypocone merging at the same time with the protocone. The third molar illustrated here by figure 137, *o*, and taken from Lenhossek clearly shows the way in which this process takes place. According to Lenhossek it is typical for the third molar to have only three cusps. Zuckerkandl found this number in 71.4% of European races and in 62.3% of non-European; Hildebrand arrived at 60%. It seems that these figures apply to cases in which the metacone was present and the hypocone lost, that is to say, it had become merged with the protocone. Apart from this diminution there is no essential difference between third and second molars of recent man in regard to the general appearance and special pattern of the crown. This is especially true of the lack of wrinkles and the simplification of the pattern.

The root in most cases is represented by more or less fused branches. Hildebrand (1908) found a single conic root in 43.4% and two fused branches in 21.1% with the buccal branches grown together. As to the manner of connection of crown and root there is no difference of particular note between the three molars.

Among the third molars of the Neanderthal group the characteristic diminution in general size is very pronounced in the Rhodesian man (Carter, 1928, fig. 20) and in the Steinheim skull (Berckhemer, 1933). As much as can be judged from the strongly worn molars of Rhodesia and Steinheim (fig. 132) the metacone has undergone a considerable reduction and the hypocone is lacking completely. There is also a considerable diminution to be observed in the case of the Sacropastore skull according to the photograph and description by S. Sergi (1929), but the hypocone

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* Dr. W. K. Gregory very kindly supplied me with casts of the jaws.

here is apparently still present. In the third molar of La Quina the tooth, according to H. Martin (1923) and the photograph, is flattened in mesiodistal diameter at the expense of the two distal cusps but the reduction as a whole is not too extensive. The same seems to be true for the right molar of the Mousterian youth while the left one, according to the cast and photograph, exhibits a remarkable reduction in which again the metacone is mostly affected. According to Gorjanovic-Kramberger (1906) the third molar of Krapina has only three cusps with a strongly reduced hypocone; this statement seems to apply to the case illustrated by that author in Plate XIII, fig. 3 and reproduced here in figure 131. It is evident, however, that in this case the metacone is much more involved in the reduction than the hypocone. This Krapina molar (fig. 131) and those of the Mousterian youth reveal some more details of the special pattern of the chewing surface. The surface is covered by characteristic wrinkles, especially in the area of the mesial and distal marginal edges, thus resembling the conditions existent in the *Sinanthropus* molars represented by figures 128 and 129 in regard to the mesial edge and by figures 135 and 136 in respect to the distal one. In addition, the presence of the triangular field in the mesial region of the molar described above for *Sinanthropus* molars is distinctly recognizable in the Krapina tooth.

As to the roots of the Neanderthal molars Gorjanovic-Kramberger described one tooth with a tripartite root, while in the remaining the branches had grown together. In La Quina both molars show three separated branches like in *Sinanthropus* given in figure 135.

It is general use to speak of the third molar of recent man as a tooth well on the way of a complete elimination or at least as one with distinct signs of a progressive diminution. Such a view, indeed, can be based on very convincing facts. But if such a fate of the molar is considered to be typical only for recent man or the hominid group, then the view becomes erroneous. It has been shown earlier that the third upper molar may almost in all families of the primate stock be considerably smaller in general than the second or the first molar and in numerous cases the difference in size and shape is very pronounced. This does not only hold good for the recent primates but also for extinct ones, as for *Dryopithecus* and to a certain extent also for the fossil orang. Therefore in this respect we are dealing with a general peculiarity of the primates regardless to which systematic group the species concerned may belong.

In the case of hominids, at least in so far as recent man is involved, it can be proven that not only a reduction takes place but also that there is a distinct tendency towards elimination of the tooth entirely. Whether or not the latter phenomenon has also occurred in *Sinanthropus* and in the representatives of the Neanderthal group cannot at this time be ascertained because the number of completely preserved adult maxillæ with all molars in place is too small (La Ferrassie, La Quina, Le Moustier, Rhodesia, Sacropastore, Spy I and two *Sinanthropus* maxillæ). However, even if such should be the case, it could not be taken as characteristic for hominids since the loss of the third molar also occurs in gibbon, orang and chimpanzee (Selenka 1899, Remane 1921), while its complete disappearance in gorilla has not been noted hitherto.

The manner in which the diminution of the third molar is manifested is the same everywhere. It consists either of a decrease in all dimensions or of a decrease chiefly in mesiodistal diameter or in a combination of both. But in all cases the metacone is the most affected, while the hypocone merges more or less with the protocone. The root takes part in this process by its three original branches exhibiting a clear tendency toward fusion in order to form a single root. But this process already occurred in the second molar of *Sinanthropus*.

The third upper molar of *Sinanthropus* shows all the peculiarities characteristic for the diminution described. In none of the seven specimens available, however, at the moment has the reduction of the hypocone reached such a high degree as is found in recent man or in Rhodesian man or in the Steinheim skull. As to the general shape and the special pattern the *Sinanthropus* third molar resembles closely the first and the second, so that all statements made above in regard to the relation of the *Sinanthropus* molars to those of anthropoids on the one hand and to recent man on the other hold good also for the third molar. The fact that the teeth of the Neanderthal group approach closer those of recent man than those of *Sinanthropus* is again revealed by the appearance of this molar.

The Carabelli tubercle.

One special feature peculiar to the upper molars of recent man has aroused great interest because of the alleged phylogenetic importance attributed to it. This feature is represented by a tubercle more or less developed, which occasionally is found at the lingual surface of the protocone, generally in the first molar and less frequently also in the second and third molars. According to the author who described it first, this tubercle is known as "tuberculum anomalum" or the Carabelli cusp or tubercle. I do not intend to enter into a detailed discussion of this formation and to refer to the extensive treatises by de Terra (1905) and Lenhossek (1922).

According to Carabelli the tubercle rises near the neck of the crown and with its tip projects freely in the mouth cavity for some distance from the crown. It results from this description that it concerns those cases in which this formation is very pronounced. Yet it is characteristic for this structure to show an extraordinary variability. According to Lenhossek who has given the best and most detailed description, the most frequent form "the normal form" is represented by a half-moon shaped furrow coursing parallel and close to the mesiolingual contour of the protocone and turning its convexity toward the chewing surface. The outer region bordered by this furrow projects more or less and lies upon the mesiolingual corner of the protocone like a scale. However, Lenhossek adds that the "cusps" in question frequently appear not as a new formation superposed on the protocone but merely as a separated portion of the protocone itself which must be rather small if the "cusp" is detached from it. In figure 334, *a* and *b*, which represents the first molar of a recent Chinese, the condition described by Lenhossek is very clear. In a great number of cases not even this stage is realized, the entire feature being restricted to a faint and short fissure or pit near the chewing surface of the mesiolingual corner of the protocone. Unfortunately, it is impossible to give exact figures on the occurrence of the formation because of the difficulty experienced in determining the varying degrees of development with sufficient certainty. Lenhossek found a Carabelli "cusp" in the first molar in 37.5%; it was found well developed in 10.2%; faintly or represented only by a small pit in 27.3%. Bolk (1915) stated to have noted that the formation in question occurs in the form of a real tubercle in 17.4% and in that of a small pit in 44.3%.

In any case, there is in recent man a special formation at the mesiolingual corner of the protocone which ranges in appearance from a small pit to a big cusp-like protuberance in c. 15% to c. 50%. This relatively frequent occurrence in recent man gained a phylogenetic interest the moment Cope (1889) described the presence of an "accessory internal tubercle" in Lemur which he brought into relation with the Carabelli tubercle and when Batujeff (1898) stated that in the first place the Carabelli tubercle occurred much more frequently in Europeans and secondly that it did not occur in anthropoids but only in baboons. Adloff (1908 and later) even went further by considering the existence of the tubercle in recent man as well as in lower primates and its supposed complete absence in anthropoids as a distinct proof that man could not have been derived from an anthropoid stock but directly from some low primate type. He believes that the Carabelli tubercle represents a regressive formation which must have been more developed or at least existed in the same degree in the ancestors of recent man and was now on the way of being reduced. In contrast to this belief de Terra (1905) considered the tubercle as a progressive feature determined to enlarge the chewing surface as compensation for the gradual loss of the second and third molar and Gorjanovic-Kramberger (1906) held the same view as de Terra with respect to the progressive character in recent man.

If Adloff's view were accepted as being correct, then it may be expected to find the Carabelli tubercle to occur more frequently in fossil hominids than in recent man and in addition to the reduction in the latter, this cusp would be met with in a more advanced stage of development in those fossils. As a matter of fact, the reverse is true. To begin with, there are twenty-two *Sinanthropus* upper molars and if Zdansky's molar is included, twenty-three molars available for a basic study. A Carabelli "cusp", however, is not to be found in whatever form in any of the cases, with the possible exception of the third molar illustrated in figure 120. But even in this case there does not exist a real tubercle but only an irregular furrow or fissure there where the structure in question is usually found. Its course corresponds, it is true, to that in recent man (compare fig. 334) but the lingual portion of the protocone separated by that furrow is a small part of the protocone itself and not a special accessory tubercle as is incontestably proven by the outline of the cone.

In connection with the Neanderthal man Adloff himself (1908) and Gorjanovic-Kramberger (1906) claim the presence of the Carabelli tubercle on the Krapina molars. The former author states that he has observed the presence of "cusps" on all molars at his disposal, even though in some cases they could just be traced. In no case, however, did the tubercle reach the level of the protocone and such an independence as in recent man. Adloff gives an illustration of such a case in Plate VIII, fig. 38 and Gorjanovic-Kramberger in Plate XIII, fig. 4. It seems that both these cases chosen for the purpose of illustrating the Carabelli tubercle constitute the best from the Krapina collection. Gorjanovic-Kramberger's molar is reproduced here in figure 123, thus making it possible to form a correct judgement of the real character of that "cusp". There is no doubt, what is called "Carabelli cusp" here is nothing else but a very small part of the protocone itself separated from the main part by a small triangular pit at the mesiolingual corner. In the case reproduced by Adloff the conditions are exactly the same except that the impression here is located somewhat nearer to the neck of the crown. Therefore, according to the various authors concerned, the so-called "Carabelli cusp" of the Krapina molars corresponds to such cases of recent man only in which this cusp is merely represented by a small pit. In the Mousterian youth both first molars show the same feature according to the photograph and the statement by Gregory (1922). Whether or not the molars of the other Neanderthal hominids possessed a real Carabelli "cusp" or an equivalent pit cannot be ascertained because of the worn condition of the dentition, but at any rate, the cusp could not have been a large one for, if so, its presence should be discernible despite attrition.

New light has been shed on the entire question by a more recent statement made by Adloff (1932). In connection with the description of the dentition of *Australopithecus africanus* Dart Adloff records in the left M^1 the equivalent of a "Carabelli cusp" being indicated by the presence of a small pit in its characteristic place at the mesiolingual corner of the protocone. Adloff writes that Dart verified the correctness of his observation by checking it on the original. Indeed, "a very, small impression" as Dart describes it is to be recognized but not a real tubercle. Adloff in accepting this interpretation offers the explanation that such a small pit must be considered to be the earliest indication of a tubercle on the way towards being separated. I therefore propose to term the pit in question "Carabelli pit" in order to distinguish it better from the "Carabelli cusp." In figure 115 the *Australopithecus* molar with that pit is reproduced. It corresponds in its position exactly to that of the Krapina molar of figure 123.

Adloff correctly notes in the publication quoted that the anthropoids show a cingulum in that place. This cingulum is clearly seen in *Dryopithecus* (fig. 116) and gorilla (figs. 117 and 331). The pit or furrow corresponds to that spot where the cingulum rises from the base of the crown meeting the mesial edge. With reference to the cases given in figures 116 ond 117 there remains no doubt that we are dealing with a characteristic cingulum, but in some cases, however, the greatest part of it is lost and only a pit or a furrow persists on the mesiolingual corner of the protocone (compare figs. 116 and 117 with figs. 115 and 123). Nevertheless, the latter feature is not at all restricted to the hominids as surmised by Adloff—its presence in *Australopithecus* ascertained by Adloff himself is a plain counter-proof—but occasionally will be found to be well developed in anthropoids, especially in the fossil types. For instance, Glæssner's *Dryopithecus darwini* (fig. 335) exhibits it in an excellent way. By a furrow with a very fine hole at its base and two dot-like elevations the feature in question is also represented in an upper molar of a fossil orang (fig. 336).

Since the Carabelli pit is located near the chewing surface, it will not be found in molars with a high degree of attrition. As to recent anthropoids the first molars of gorilla usually show a well developed cingulum, in chimpanzee the cingulum is reduced to a short furrow in the characteristic place and occasionally combined with a small pit. In the orang there exists in certain cases a complicated pattern which must be considered as a derivation from the cingulum. The Carabelli pit common to recent man and existent in Neanderthal man can thus be found in the same degree of development in anthropoids, fossil as well as recent. Adloff's contention that the presence of a "Carabelli cusp" in recent man implies a fundamental difference between man and anthropoids must hence be refuted because it stands in contrast to the actual facts. This statement, as a matter of fact, only concerns the "Carabelli pit." But what are the conditions of the Carabelli tubercle?

It should be noted that Remane (1921) described an occasional occurrence of the Carabelli "cusp" also in anthropoids. He found its presence in two cases of second molars of a gorilla. It must be admitted, however, that the real cusp is undoubtedly far more frequent in recent man than in anthropoids in which it may occur in exceptional cases. Furthermore, it is likewise obvious that in all fossil hominids known hitherto (*Sinanthropus* and Neanderthal man) a real "cusp" does not exist. Thus Adloff's assumption that the cusp in recent man must be considered to represent a regressive formation, being the remnant of a still more developed cusp in his ancestors, is apparently in contrast to the actual facts. On the contrary, such formations as in excess to the normal form of a pit or furrow and offering the aspect of an accessory cusp are only found in recent man and constitute secondary acquisitions here, according to de Terra and Gorjanovic-Kramberger. This implies that there exists a tendency to exaggerate under certain circumstances a feature which grows from the remains of a formation clearly in regression in hominids, namely the cingulum.

Such tendencies are not at all restricted to the first upper molar. They are very pronounced in the third molar of recent man and often present the strangest pattern formed by accessory cusps in various places. It was at no time surmised that all these variations must be considered equivalents to special structures of unknown ancestors. I was able to show in the preceding pages that in recent and Neanderthal man there is a general tendency towards enlarging the tubercular structures on the lingual surface of all upper teeth, namely incisors, canine and premolars (see above and figs. 21, 24, 48, 76). Similar tendencies may also be seen in other members of the primate group. *Hylobates* is a good example. Adloff (1908) described the occurrence of the Carabelli cusp and illustrated it in his figure 78 *b* (Plate 20). However, the presence of this cusp here does not constitute a rule but rather an exception. In *Cebus capucinus* I found in both third molars a large and high accessory cusp on the lingual surface between protocone and hypocone (fig. 337) but not once in any of the Platyrrhinæ. Bolk (1914) also ascertained the presence of such accessory cusps in *Cebus*. It seems that occasionally the cingulum gives origin to some cusp-like formations. One of the best known is the hypocone itself which is derived directly from the cingulum according to the general belief (compare fig. 331). Adloff (1908) described and figured (Plate 27, fig. 100) a "Carabelli cusp" on all molars in a lemur. As is evident from figure 338, however, this feature cannot be compared directly with the same formation in recent man, for it merely represents a rounded off thickening of a low cingulum projecting directly lingualwards on the mesial portion of that surface. A tubercle of exactly the same kind but much smaller projects on the distal portion occupying the site of the hypocone. But while the latter disappears in the second and third molars, the mesial tubercle here is preserved. More than this, the mesial tubercle is also present in the last premolar. In other prosimians this tubercle is lacking, and the space of the distal one taken by a hypocone. These facts demonstrate the highly variable character of such structures. If all intermediary stages are missing, then it is impossible to homologize those inconstant structures with accidental formations of phylogenetically more advanced types. Be it as it may, it is evident that the idea of a fundamental difference between the hominids and the anthropoids and the direct derivation of the former from low primates based upon the presence or absence of a Carabelli pit or cusp is without any fundamental support. The pit represents a remnant of the cingulum common to all primates including the anthropoids and the tubercle is an accidental variation without phylogenetic significance, with the distinct tendency to increase in size and frequency in recent man. I agree in this respect with Gregory (1922) who voices a similar opinion.

For the sake of completion I also wish to refer briefly to the conception held by Bolk (1914) who considered the Carabelli tubercle in conformity to his "dimere theory" as the representative of a "tritomere", that is to say, as a manifestation of a third dentition located behind his "deuteromer" (represented by the protocone and hypocone) or better lingually from it. The conditions in *Sinanthropus* which is certainly closer to the primitive stage than recent man do not support Bolk's suggestion since the supposed "tritomere" is much less pronounced in the former than in the latter.

b. LOWER MOLARS

First and second molars (figs. 139-142, 144, 145, 147, 148, 155, 161-166, 180, 283-290, 294, 339)

The description of the first and second molars is assembled because of their close resemblance which makes it difficult to distinguish them when isolated. In this respect *Sinanthropus* differs considerably from recent man because in the latter the second molar usually appears rather reduced in size and pattern when compared with the first one. Thus, the decision whether we are dealing with a first or a second molar is rather complicated in the case of *Sinanthropus*. However, the fact that of the 24 first and second lower molars at our disposal 7 first and 6 second were found *in situ* makes possible a rather correct determination of the isolated teeth. Additional and may be found in the age of the teeth which is approximately determinable by the degree of wear and the conditions of the roots inasmuch as there exists a greater probability for the preserved germs to represent second rather than first molars, since the presence of such infantile mandibles as may be presumed by germs of first molars has not been confirmed.

The molar material comprises six unworn or only slightly worn teeth and is thus sufficiently large in number to permit a thorough examination of the characteristic pattern. The first *Sinanthropus* molar found and subsequently described by Black (1927)—fig. 144—has already undergone a further stage of attrition when compared with the new material. Eight first and five second molars probably belong to male individuals and six first and five second molars to female.

One of the most characteristic features of the crown is its lowness in relation to its length and breadth as demonstrated in figures 139, 140, 148, 339, which represent unworn or only slightly worn teeth. Combined with this peculiarity is a marked convexity of all four outer surfaces of the crown, especially of the buccal one. The convexity is due to a swelling located at the basal part of the crown which produces a bulbous formation, especially on the buccal surface (compare also fig. 180). In connection with this structure the upper part of the crown represented by the protoconid and hypoconid inclines strongly lingualwards. There is no doubt that the structure in question has to be considered as the remainder of a cingulum which is very pronounced in the corresponding place in gorilla (figs. 157 and 181), to a lesser extent—like in *Sinanthropus*—in orang and chimpanzee.

The presence of a cingulum originally is furthermore proven by other particularities of the buccal surface. The most conspicuous of them and strongly developed in certain cases (figs. 140, *b*; 148, *b*; 165, *b*, *o*; 339, *b*, *o*) is a long S-curved indentation emerging close to the mesial slope of the protoconid and descending obliquely to the just mentioned basal swelling where it ends. In the case given in figure 339 it continues into the fissure separating the protoconid from the hypoconid. This indentation represents nothing else but the ascending mesial portion of the cingulum which rises in gorilla (fig. 181. M_1, M_2) to a higher level than its distal portion. The buccal surface of the protoconid proper which is delimited by that indentation occasionally also shows a fine striation (fig. 148). In the case of figure 139 *b*, *m*, *o* (294) in which the indentation, it is true, is absent, the striation is composed of a fine denticulation ending just below the level of the chewing surface. Another feature also correlated with the original presence of a cingulum is that the fissures cut in deeply and separate the protoconid from the hypoconid and the latter from the mesoconid. Both fissures especially the first one end in small pits overshadowed by the upper border of the basal swelling (figs. 139, *b*, *o*; 148, *b*; 180, M$_2$), a feature which resembles the formation of stylar cusps in lower primates, and one which is also indicated in anthropoids (figs. 156, 158, 181, 297).

The lingual surface exhibits no special pattern, except that the fissure separating the metaconid from the entoconid is well developed and that in some cases a more or less distinct furrow also separates the entoconid from the mesoconid or the "tubercle 6", respectively. The mesial and distal surfaces do not show any special features, with the exception that the marginal edges uniting the corresponding cusps may occasionally be slightly crenulated, either the mesial and distal edges or only one (figs. 139, *m*; 140, *d*; 165, *l*).

The cusps are in all cases well developed. It is difficult however to define which of them is the highest and in which sequence the remaining ones come. The reason for this difficulty is the fact that the neck of the crown does not form an even plane (figs. 139, *l*; 161, *l*). It seems to me that both mesial cusps are somewhat higher than the distal and that the metaconid is higher than the protoconid, of course, only in unworn molars.

In order to describe adequately the extremely complicated pattern a standard type molar is chosen, namely one which unites most of the features characterizing *Sinanthropus* such as is illustrated in figure 165, *o*. This molar which I designate as standard type I also represents the basic model for the pattern schema given in figure 155. Although the chewing surface is covered by a great number of accessory ridges of the same kind as those described in the upper molars, it is easy to recognize the main furrows delimiting the single cusps and thus to define the fundamental pattern of the surface. In the case in question there are six cusps, three on the buccal and three on the lingual side which are separated by a longitudinal furrow coinciding exactly with the longitudinal axis of the tooth. The largest cusp is the metaconid, it exceeds the other, especially the protoconid, in longitudinal as well as in transversal extension. The sequence of the other cusps with respect to size is: protoconid, entoconid, hypoconid, mesoconid, accessory tubercle 6. All six cusps are connected by major ridges which encircle an oblong inner area, the chewing surface proper. Within this area the cusps are separated by major furrows which continue to the corresponding outer surfaces cutting into the major ridges on their course. There is only one exception, namely the major ridge uniting the protoconid and the metaconid and representing the mesial edge of the chewing surface. This edge is never interrupted by such a furrow. The special arrangement of the cusps consists of that the protoconid, hypoconid and mesoconid are entirely situated within the buccal moiety of the tooth, while the metaconid, entoconid and tubercle 6 occupy the lingual half. As the metaconid is longer than the protoconid it does not only meet with the latter but also with the hypoconid. Gregory (1922) and Gregory and Hellman (1926) called this special arrangement the "*Dryopithecus* pattern" because it characterizes the lower molars of this fossil anthropoid. Gregory (1916) reeds

The "tubercle 6" is intercalated between the mesoconid and the entoconid and proves its independency from the two adjoining cusps by the existence of separating major furrows on each side. It is represented by one large wrinkle emerging from the distal edge of the chewing surface. The area occupied by the space between the mesial edge and the inner slopes of the protoconid and metaconid shows a triangular form and resembles closely the triangular area of the upper molars described above (compare figs. 113 and 114, *o* with fig. 165, *o*). It is limited by a V-shaped furrow caused by a bifurcation of the longitudinal major furrow on its mesial end. A real "fovea anterior" does not exist unless one should choose to apply this term to the place of this bifurcation. The same holds good for the "fovea posterior" which likewise does not exist unless one considers it to be that point at which the furrow separating tubercle 6 from the entoconid deviates from the longitudinal major furrow.

It is evident from the preceding description that the trigonid represented by both mesial cusps, the protoconid and the metaconid, is larger than the talonid composed of the four remaining cusps. The prevalence of the trigonid does not only involve the breadth but also the length. I will return to this question below.

As is true in all other types of teeth the variation in the appearance of the lower molars of *Sinanthropus* is very great. This variation concerns in particular the size and arrangement of the cusps and the formation of tubercle 6 as an independent cusp. For instance, in figure 339 where the characteristic outer relief of the protoconid is well developed and the "*Dryopithecus* pattern" very pronounced on account of the preponderant size of the metaconid, tubercle 6 is missing and replaced by the mesoconid which has shifted somewhat beyond the midline of the tooth. In consequence thereof the longitudinal furrow shows a bifurcation on its distal end with its branches enclosing the mesoconid. Another interesting variation concerns the mesial end of the furrow and the triangular area. Instead of this area being delimited by a V-shaped fissure there is a narrow zone formed by a transversal fissure. A strongly developed accessory ridge representing a mesial portion of the metaconid slope rises above the lingual side of that fissure. I have designated this type as type II.

Between both these extreme variations there are other approaching in some details type I and in other type II. The molar illustrated in figure 139, *o* shows the pattern of type II with regard to the configuration of the distal end of the longitudinal furrow, that is to say, the tubercle 6 is missing and the mesoconid has shifted beyond the midline, while the triangular area on the mesial end is easily recognizable in spite of the attrition. The molar of figure 140, *o* belongs in all details to type I, except that tubercle 6, although present, is not distinctly separated from both adjoining cusps. The molar given as figure 144—Black's molar—likewise belongs to type I; this tooth is of special interest because it demonstrates that in spite of its considerable attrition the general arrangement of the cusps can be determined by the characteristic course of the major furrows. Small point-like or stroke-like impressions indicate here the original presence of furrows even in the region of the heaviest attrition. Thus it may be seen that the V-shaped fissure existed on the mesial end, that the mesoconid was situated entirely on the buccal side and that tubercle 6 must have been present and separated by a deep furrow from the entoconid. The molar of figure 163 also represents type I with two exceptions, namely that tubercle 6 is present but appears to be a somewhat independent wrinkle of the entoconid. The second exception concerns the configuration of the triangular area; instead of it the mesial edge is very narrow and meets with two distinct wrinkles, a buccal and a lingual one, the former representing a separated portion of the protoconid, the latter such a section of the metaconid. This case is similar to that in figure 339 (type II) with the only difference that the protoconid wrinkle is absent in the latter. The molar of figure 164 represents a characteristic type I with tubercle 6 transformed into a relatively large cusp and therefore somewhat shifted to the buccal side. The molar of figure 166 represents type II but the triangular area is the same as in type I.

An exact classification of strongly worn teeth is, of course, difficult. The molar of figure 141 seems to belong to type II and that of figure 145 to type I. However, in all these cases the metaconid is the largest cusp and the "*Dryopithecus* pattern" as well as the presence of at least 5 cusps are recognizable. In this respect it is irrelevant whether we are dealing with a first or a second molar, since a conclusion may be reached from the appearance of the completely intact teeth *in situ*.

Certain exceptions, however, exist. All unworn or only slightly worn molars are oblong with the longer axis represented by the longitudinal axis of the tooth. From this shape it may be concluded that worn oblong teeth also, even though their pattern is obliterated, must have been in possession of five or six cusps. Some of the worn molars exhibit a quadratic form such as the one selected as the most typical tooth in this respect and illustrated in figure 142, *o*. Although in this case the trigonid is broader than the talonid, the protoconid seems to be larger than the metaconid. But it should be taken into consideration that the metaconid is much more worn than the protoconid and that the faint traces indicating the transversal furrow show the original presence of a *Dryopithecus* pattern. The quadratic form of this molar seems therefore to be a consequence of the very strong attrition of the contact sides as revealed by the corresponding views (*m*, *d*). As is evident from figures 141 (*m*, *d*, *o*) the attrition at such places always exercises great influence upon the shape of the molars; it diminishes the length while the breadth remains unchanged. This is the reason for my skepticism toward the indiscriminated use of the length-breadth index of molars as a reliable criterion for comparison purposes.

In the cases illustrated in figure 161 the molar is also quadratic and worn on the contact sides, but here, nevertheless there exists a *Dryopithecus* pattern as revealed by the course of the transversal furrow and the position of the corresponding buccal and lingual fissures. In figure 147 on the other hand which also represents a quadratic molar with considerable attrition on the contact sides, the *Dryopithecus* pattern has been lost with the metaconid exhibiting the same length as the protoconid. But there is a connection between the hypoconid and the metaconid brought about by a narrow wrinkle-like continuation of the former which crosses the intersection of the longitudinal furrows. The same arrangement is peculiar to the molars of the Neanderthal group (compare figs. 147, *o* with 149-154).

The inner slopes of all cusps are covered by wrinkles, that is to say, by accessory ridges and furrows. The degree of development is in all molars the same regardless whether it concerns a first or a second one. As is true of the upper molars these wrinkles represent a very characteristic feature of the lower molars of *Sinanthropus*. The wrinkles are present not only in germs (figs. 164, 165 and 166) but also in erupting teeth (fig. 163) and in completely erupted teeth (fig. 140). They will be lost in proportion to the advance of attrition but even in strongly worn molars accessory furrows which occasionally cut in quite deeply into the surface of the tooth may still indicate their original presence and course. The belief, defended with astonishing obstinacy by Adloff (1908-1937), namely that the wrinkles are only accidental transitory structures without any special significance for classification or for phylogenetic questions has become totally void of even the slightest foundation because of the *Sinanthropus* molars (see below). It is true, there is a great variation in wrinkles with respect to size, number and position. Their general character, however, is so constant that it is possible to define their arrangement and their relation to the cusps and other structures of the chewing surface.

The character in principle is the same as in the upper molars for which detailed information has been supplied above. The schema reproduced in figure 155 may serve as an appropriate illustration: the major fissures separating the cusps are indicated here by heavy lines, the accessory by dotted lines. The wrinkles cover the inner slopes of the five cusps. In addition, they are also present in the triangular area where they emerge from the mesial edge. Tubercle 6 appears to be a large wrinkle, emerging from the distal edge and having attained a certain independency (figs. 163, 164, 165). In most of the cases each of the slopes of the main cusps shows three wrinkles—or—when the number is increased—three groups of wrinkles the middle one of which is the largest, while those on either flank are smaller. The variations consist of a decrease or increase of the number or stoutness, of a stronger development of individual wrinkles and of secondary sub-divisions. The increase in number and the two last mentioned variations are chiefly found in the metaconid. The stronger development is manifest mainly in a stronger growth in length, so that the wrinkles are either curved or winding.

The three wrinkles pertaining to a cusp are usually so arranged that the middle wrinkle emerges from the tip of the cusp, while those on the sides start from the major ridges going out from the tip to either side. In descending the wrinkles of one cusp meet at the foot of the slope those of the opposite or neighbouring cusps so that the furrows separating the cusps are bordered by very sinuous lines (fig. 155). Despite such a complication of the chewing surface the wrinkles do not at all conceal the fundamental structure of the molar (fig. 138). The cusps remain the characteristic feature with the wrinkles closely restricted in arrangement and course to the individual cusps.

TABLE XVIII

Measurements of first lower molars

		Molars *in situ*								Isolated Molars							
		180 284 No. 96 289 ♀	145 No. 97 ♀	140 No. 98 ♂	148:286 No. 99 ♂	283 285 No. *100* ♂ c/307	No. *101* ♀	141:287 288 No. *102* c/309 ♂	Average	144 No. 34 ♀	147 No. 35 ♂	139 311 No. 36 ♂	138 No. 37 ♂	142 311 No. 38 ♀	339 No. 137′ ♂	No. 147′ ♂	Average
crown	height	(3.8)	7.2	8.4	7.8	(5.3)	—	(4.3)	7.8	7.1	(3.5)	7.7	—	(4.5)	7.3	(4.6)	7.6
	length	11.8	11.9	13.6	13.4	13.2	11.3	13.0	wrong *12.6*	12.2	12.5	14.1	—	9.9	13.0	12.3	*12.6* wrong
	breadth	11.2	11.1	12.6	12.2	12.5	10.6?	12.6	*11.8*	10.9	12.6	12.8	12.0	10.1	11.7	11.7	*11.7*
	length-breadth index	95.1	93.3	92.7	91.1	94.8	94.2	97.2	*93.7*	89.4	100.7	90.8	—	102.0	90.2	—	*93.3*
	trigonid breadth	—	11.1	12.6	12.2	12.5	—	12.6	*12.2*	10.9	12.6	12.8	—	10.1	11.7	—	*11.9*
	talonid breadth	—	10.7	12.2	11.9	12.3?	—	12.3	*11.9*	10.6	12.5	12.5	—	9.6	11.3	—	*11.6*
	trigonid index	—	93.3	92.7	91.1	94.8	—	97.2	*96.8*	89.4	100.7	90.8	—	102.0	90.2	—	*94.5*
	talonid index	—	90.1	89.9	88.8	—	—	94.7	*90.8*	87.1	100.0	88.8	—	—	87.3	—	*90.8*
root	height: mesial	—	—	—	—	—	—	16.1		(11.7)	14.7	(12.4)	—	13.1	(14.2)	—	
	distal	—	—	—	—	—	—	15.5		(10.7)	14.7	(13.4)	—	14.2	(12.7)	18.5	
	length: total	10.2	—	—	10.9	11.2	—	10.5		9.0	10.7	10.5	—	8.9	9.1	11.3	
	mesial	—			—	—		4.0		4.1	4.4	4.5		4.1	4.4	5.1	
	distal	—			—	—		5.7		4.4	4.9	4.7		4.6	4.3	5.8	
	breadth: total	10.2	—	—	11.9	10.8	—	11.1		9.9	9.9	10.8	—	9.7	10.2	11.0	
	mesial	—			—	—		—		9.9	9.9	10.8		9.7	10.2	11.0	
	distal	—			—	—		—		7.3	8.9	9.9		7.9	8.3	10.4	

TABLE XIX

Measurements of second lower molars

		Molars *in situ*							Isolated Molars				
		180'172:173	164	163:286		283.	287		166	165:290	161		
		284:289 No. *106* φ314 ♀	No. *107* ♂	No. *108* ♂	No. *109* ♂	28. No. *110* (♂ φ207	288 No. *111* ♂ φ204	Average	No. 43 ♀	No. 44 ♀	No. 45 ♀	No. 138' ♂ ?	Average
crown	height	(4.5)	9.1?	7.0?	(5.0)	6.7	(5.1)	*7.6*	(6.4)	(6.8)	(7.4)	(5.2)	—
	length	11.9	12.9	13.2?	12.6?	12.5	12.6	*12.6*	12.8	13.1	12.1	11.3	*12.5*
	breadth	11.4	13.0?	12.7?	12.9	12.7	12.6	*12.5*	11.1	11.5	12.0	11.5	*12.1*
	length-breadth index	95.9	100.7?	96.4?	102.3?	101.3	100.0	*100.0*	87.1	88.0	99.3	101.9	*96.8*
	trigonid breadth	11.4	—	—	12.9	12.7	12.6	*12.4*	11.1	11.5	11.8	11.5	*11.9*
	talonid breadth	11.4	—	—	12.9	12.7	12.4	*12.3*	10.7	10.9	12.0	11.5	*11.8*
	trigonid index	95.9	—	—	102.3	101.6	100.0	*98.4*	86.8	88.0	97.6	100.7	*95.3*
	talonid index	95.9	—	—	102.3	101.6	98.5	*98.3*	83.8	83.3	99.3	100.7	*94.5*
root	height: mesial	—	—	—	—		—		—	—	15.5	—	
	distal	—										16.0	
	length: total	10.2	—	—	—	11.0	9.2		—	—	9.4	9.3	
	mesial	—				—	—					3.9	
	distal	—				—	—					4.2	
	breadth: total	10.3	—	—	—	11.3	10.2	—	—	—	9.5	9.7	—
	mesial	—				—	—				9.5	9.7	
	distal	—				—	—				7.7	7.2	

The root of the molars is very strong. In most of the cases it is composed of an undivided portion forming the neck part of the root (stem) and a divided portion represented by two branches, a mesial and a distal one (figs. 139 (294), 141, 142). Black (1927a) when describing the first discovered *Sinanthropus* molar laid stress upon the fact that the undivided portion which he termed "corpus" is very high and especially developed on the lingual side. This feature, indeed, is characteristic for *Sinanthropus* molars. It depends upon the fact that the enamel of the crown descends deeper on the buccal than on the lingual side (figs. 139, 142; cf. also the section on taurodontism). In fully developed roots (figs. 141, 142, 307, 309, 314) it may be seen that the mesial branch of the root differs from the distal in so far as the former is lower, shorter (*b*, *l*) but broader (*d*)—cf. table of measurements above. The mesial branch is slightly curved toward the distal, while the latter straighter than the other, deviates distally. Whereas the distal branch ends with a single blunt apex, the mesial one bifurcates into two more or less separated tips (figs. 139, 141, 142, 147, *m*). Both branches show distinct depressions along the longitudinal axis of the mesial and distal sides, that of the former side being in most cases wider and shallower than that of the opposite side (figs. 139, 141, 147, 148, *m*). The depression of the mesial branch becomes deeper in apical direction toward the bifurcation. In some cases (figs. 139, 142) a small third portion is again subdivided from the lingual apex.

The neck part of crown and root shows two different types. One type is illustrated in figure 139, the other in figure 142. The first one is characterized by a distinct constriction of the root in the neck region with this phenomenon accentuated by a strong projection of the four outer surfaces of the crown. In the second type the crown appears to be as a quadratic block showing the same robustness as the stem of the root. The block-like shape of the crown is for instance very pronounced in all three molars of the female mandible A II (figs. 180, 289). Although the block-shape is more distinct in cases with strongly developed contact facets, it does not depend entirely upon the latter but is a genuine character of the molar. Among the molar material at our disposal this block type is especially apparent in the small molars which probably belong to female individuals.

The characteristic appearance of the *Sinanthropus* molars may best be understood by a comparison with the anthropoid molars (figs. 156-160, 181, 243, 297). Beginning with *Dryopithecus* (fig. 159) there is on hand an excellently preserved germ which shows all characteristic features. This germ has been attributed as pertaining to *Dryopithecus germanicus* (*rhenanus*)—Trochtelfingen. In its general shape the molar corresponds perfectly to *Sinanthropus* standard type I given in figure 165, *o* in that there is the same oblong form and the trigonid much broader than the talonid. The cusps are well developed; three of them occupy the buccal moiety of the chewing surface; the conditions of the lingual side, however, are not as distinct. A tubercle 6 is lacking with its space occupied by the entoconid but there is a distinct accessory cusp on the mesial border of the latter, seemingly a separated portion of it. Like in *Sinanthropus* the metaconid is the largest cusp followed by the protoconid. The hypoconid is the smallest cusp of the main cusps. The arrangement of the furrows exhibits in accordance with the size and arrangement of the cusps that pattern described above as characteristic for *Sinanthropus* and which Gregory termed the "*Dryopithecus* pattern". The resemblance between *Sinanthropus* and *Dryopithecus* goes still further, namely the cusps are covered by wrinkles arranged in exactly the same manner as in *Sinanthropus*, differing in so far that the wrinkles are less numerous in *Dryopithecus*, apparently due to the inferiority in size of the cusps. Other differences concern the cingulum and its differentiation which, in some cases, especially in *Dryopithecus darwini* Abel (cf. Abel, 1931: fig. 89), it is true, is very well developed and then again completely lacking in other specimens (*Dryopithecus germanicus*, fig. 159). Furthermore, the trigonid portion of the molar is distinctly higher than the talonid. Instead of the triangular area of the trigonid peculiar of *Sinanthropus* the protoconid and metaconid are connected here by a bridge formed of two special wrinkles which encloses in conjunction with the mesial edge on the opposite side a deep pit. The distal end shows a similar structure with the mesoconid and entoconid united by such a bridge also consisting of two corresponding wrinkles. The mesial bridge has been designated by Remane (1921) as the "anterior trigonid crest", a determination which I consider to be incorrect (see below).

The molars of gorilla (figs. 157, 181, 297) have the same appearance as those of *Sinanthropus* with regard to the general shape of the crown, the prevalence of the trigonid in size and the number and arrangement of the cusps. The presence of a very distinct cingulum (fig. 181) has already been mentioned above. However the cusps are much higher and more pointed than in *Sinanthropus*, in particular those of the trigonid which are much higher than those of the talonid. As to the size of the cusps there is an interesting variation; in some cases the metaconid is the largest cusp followed by the protoconid but occasionally the former is smaller than the latter and in such case an accessory intermediary tubercle will often be found to be separated from its distal part (fig. 297, M_2 and M_3). In all cases the hypoconid is very small and of the same size as the mesoconid and the entoconid larger than either of the latter. In some cases there exists a well developed tubercle 6 which must be considered as a differentiation of the distal wall bordering the chewing surface and representing the distal portion of the cingulum. As in *Sinanthropus* this accessory tubercle is situated closer to the lingual than to the buccal moiety of the molar (fig. 297). Wherever the tubercle is lacking (fig. 157) there may be observed a well developed distal edge. In unworn molars the whole chewing surface is covered by wrinkles. The wrinkles show the same relation to the cusp as in *Sinanthropus*. They differ in that they are much finer in relation to the size and height of the cusps and take a much straighter course than is the case in *Sinanthropus*. They also differ in the number allotted to one cusp, the large ones having more than three and the smaller ones less. Occasionally the wrinkles are pinnated, a condition which corresponds to the subdivision observed in *Sinanthropus*. Remane (1921) called attention to the fact that the wrinkles (accessory ridges) vary considerably in the degree of their development within the different races of gorilla by being very scarce in some and rather abundant in other (for instance in *Gorilla beringei*). The mesial part of the trigonid region deserves special consideration. Remane describes the presence here of three transversal ridges. The most mesial one of them is the mesial edge (fig. 157) which forms an arched connection between the protoconid and metaconid. Then follow two straight bridges each of which is formed by two strong wrinkles emerging directly from the tip of the protoconid and metaconid, respectively. Both bridges are interrupted by a fine longitudinal fissure and between them there is a deep transversal fissure. Remane considers the mesial of the straight crests to be the "anterior trigonid crest", the distal one as the "posterior trigonid crest" and the fissure between them as the trigonid basin (fovea anterior). I consider the mesial edge proper to be the anterior trigonid crest, the mesial straight bridge the posterior trigonid crest, the pit between edge and bridge the trigonid basin and the distal straight bridge merely a secondary inconstant acquisition. I will return to this question below but nevertheless wish to refer the reader to my earlier discussion of the same problem involving the upper molars.

The general shape of the crowns of the chimpanzee molars (figs. 158, 291) is the same as in gorilla and in *Sinanthropus* with the slight difference that in some cases the breadth of the tooth here is somewhat greater in relation to its length than in the latter two. The existence of a cingulum is manifested by a strong bulbous swelling of the basal part of the lingual surface. The cusps are well developed and pointed but much lower than in gorilla. Their size and arrangement is the same as in gorilla or *Sinanthropus* if five cusps are present in that the mesoconid occupies the middle between the hypoconid and the entoconid. In some cases the metaconid is the largest cusp and the entoconid larger than the hypoconid or the mesoconid, thus resulting in the existence of a typical *Dryopithecus* pattern, but frequently the protoconid and the metaconid on one side and the hypoconid and the entoconid on the other are equal in size, so that the *Dryopithecus* pattern changes into what Gregory and Hellman (1926/27) call the cross or plus pattern. Such a pattern is present in the case illustrated in figure 158 in which, in addition, a real longitudinal furrow did not develop. As in gorilla and *Sinanthropus* the inner slopes of the cusps are covered by numerous wrinkles. They, as a whole, exhibit the same character as in *Sinanthropus* with the only difference that approximately all those which belong to one cusp emerge from its tip and then diverge. In most of these cases there is one main wrinkle and other take origin from this. Due to this arrangement the chimpanzee molar is more abundantly equipped with wrinkles than *Sinanthropus* or *Dryopithecus*. As to the trigonid area there is apart from the mesial edge only one bridge corresponding to the mesial straight bridge of gorilla, the distal one is either missing or merely faintly indicated by two curved wrinkles.

A comparison with orang molars is of particular interest because we are not only able to compare the *Sinanthropus* teeth with those of recent orang (figs. 243, *b*; 292) but also with those of a fossil orang of Southern China (fig. 243, *a*). The latter shows the typical appearance of the *Sinanthropus* and anthropoid molars. It is oblong and the trigonid distinctly broader than the talonid. The cingulum is restricted to the bulbous swelling on the lingual surface. There are five, perhaps 6 cusps with the sixth one seemingly indicated by a bifurcation of the longitudinal furrow in front of the distal wall. At any rate, there is a typical *Dryopithecus* pattern with the metaconid being by far the largest of all cusps, the entoconid and the hypoconid perhaps of the same size. The cusps are high and well pointed and their inner slopes covered by wrinkles the arrangement of which is the same as in chimpanzee. In the case of figure 243, *a* the molar is somewhat worn so that the wrinkles are only indicated by the abundance of the accessory furrows, but in other molars of more recent findings of fossil orang teeth. the wrinkle pattern is very distinct and characteristic. As to the trigonid region, there also is only one straight bridge between protoconid and metaconid which corresponds to the mesial straight bridge of gorilla. In the case of the first molar of figure 292 and the third molar of the fossil orang illustrated in figure 179, it is quite evident that the distal bridge, occasionally so well developed in gorilla, must be a secondary formation. Since here in orang there exists one big bifurcated wrinkle on each side, their mesial branches are provided with a crest and located at a higher level than the distal ones; in addition they are straight and meet each other directly. In contrast to this the distal branches of the bifurcated wrinkle are flat, curved and descend so that they never attain the character of being a connecting crest.

The general appearance of the molar in recent orang (figs. 243, *b*; 292) is the same as in the fossil type. The fact that the talonid is broader than the trigonid in the illustrated case, however, is not a rule. Incidentally, it occurs occasionally also in gorilla and chimpanzee, especially in the first molar. The cusps may be somewhat lower and less pointed than in recent orang. I also have the impression that the general character of the wrinkles shows no essential differences and that they are more abundant and finer in recent orang than in the fossil one. However, there is a distinct difference in respect to the trigonid region in that in recent orang three bridges are present (fig. 243, *b*). the mesial edge and in addition a narrow mesial straight bridge and a large distal one distinctly composed of two extensively curved wrinkles.

The first lower molar of *Australopithecus* (fig. 156) follows the general plan of the anthropoid and *Sinanthropus* molars, with the exception that the trigonid is somewhat narrower than the talonid (compare figures given by W. Abel, 1931, in his table 7) and that the metaconid has the same size as the protoconid, two phenomena which also occur occasionally in first molars of all anthropoids and *Sinanthropus*. Apart from this, however, there are six cusps with three on each moiety, tubercle 6 being well developed and separated by deep fissures from the entoconid as well as from the mesoconid. The cusps are well developed and lower and less pointed than in gorilla. In all these respects the resemblance to the *Sinanthropus* molar (fig. 165, *o*) is very striking. Like in the latter the cusps are covered by wrinkles but these structures are very coarse and not as abundant as in *Sinanthropus* and in the other anthropoids, thus are closer in resemblance to the wrinkles of *Dryopithecus* (fig. 159). The trigonid region reveals only two bridges, the mesial edge and a distal one formed by the entire slopes of the protoconid and metaconid. A buccal cingulum and its differentiations including indications of stylar cusps are well marked on the buccal side.

In regard to the roots of the anthropoid molars, their general appearance is in spite of differences in size, at least as far as gorilla and orang are concerned, the same as in *Sinanthropus*. It therefore fully explains the fact that in the latter the stem of the root, that is, its undivided part (see above), is higher on the lingual than on the buccal surface. In gorilla, orang and chimpanzee the same conditions may be found. The reason for such a peculiarity is the fact already mentioned above that the crown or better the enamel descends considerably deeper on the buccal than on the lingual side, probably as a consequence of the special manner in which the molar is placed within the alveolar process of the mandible. The other peculiarities found in *Sinanthropus*, namely that the distal branch of the root deviates and is straighter, higher, longer but narrower than the mesial branch, while the latter is slightly curved and ends in two tips, may be observed very frequently in gorilla (fig. 146, *e*). They are less pronounced in chimpanzee (fig. 146, *o*) and orang. The relation between crown and root will be treated in the chapter on taurodontism.

This survey on the lower molars of the anthropoids, recent and fossil, demonstrates very strikingly that the molars of *Sinanthropus* exhibit distinct anthropoid characters. As such the following peculiarities may be listed:

1. The length is greater than the breadth.
2. The trigonid is broader than the talonid.
3. The buccal surface is provided with a cingulum or its differentiations; in addition, the enamel descends deeper on the lingual side.
4. There are six, respectively five cusps in the former case with three occupying the buccal moiety and three the lingual one.
5. The metaconid is the largest cusp, the hypoconid in some cases smaller than the entoconid.
6. The arrangement of the cusps shows a typical *Dryopithecus* pattern.
7. The inner slopes of the cusps are covered by wrinkles in typical position and development.
8. The distal branch of the root is deviating, straighter, higher, longer but narrower than the mesial branch which ends into two distinct tips.

The only difference between *Sinanthropus* and the anthropoids concerns the formation of the trigonid region, that is to say, the trigonid ridges. This region in most of the *Sinanthropus* cases is characterized by a triangular area bordering the mesial edge and intercalated between the slopes of the protoconid and metaconid and by the absence of any elevated bridge connecting these cusps in a direct way. In all anthropoids there exists apart from the mesial edge such a second ridge which rises to the same level as the former and is separated from it by a deep fissure or pit. In gorilla there is even a third bridge parallel to the second one. However the first mentioned condition does not occur in all specimens of *Sinanthropus*, in some cases also the second eventuality is realized as in figure 163 and partly in figure 166. This fact proves that the difference in that feature cannot be a fundamental one. The question is only which of the two or three configurations must be considered as the more primitive one.

Remane (1921) in taking the feature of the gorilla molar described above as typical for anthropoids, identifies the second bridge with the original anterior trigonid crest and the third with the original posterior trigonid crest. That author derives from the special appearance of the second milk molar of gorilla, in which according to Adloff (1908) the paraconid should have been retained, the interpretation of the special conditions of the permanent molar. I am not convinced of the correctness of such a conclusion. It is no longer necessary, however, to make use of the milk molar of gorilla when searching for a primitive tooth type for comparison. For the deciduous molars of *Sinanthropus* show the paraconid and the system of the trigonid crests much more distinctly than even those of gorilla (see below). The second milk molar of *Sinanthropus* (No. 139') illustrated in figures 343 and 344, *b* in which the trigonid is best developed reveals that the posterior trigonid crest does not at all have its beginning at the tip of the protoconid but at the end of the distal main ridge, immediately at the boundary between the protoconid and hypoconid, while on the lingual side it directly meets the tip of the metaconid. The same is true for the anterior trigonid crest which likewise does not start from the tip of the protoconid proper but from the mesial end of the main ridge and is therefore undoubtedly identical with the mesial edge bordering the trigonid basin. It is evident that this arrangement is the most primitive because it is found to exist in the same way already in the molars of Eocene prosimians (cf. fig. 344, *a* and Gregory, 1922).

A comparison with the conditions of the real trigonid crests shows that neither the second nor the third ridges found in permanent molars of the gorilla (see above) correspond exactly to the trigonid crests because both start from the tips of the protoconid and metaconid. The only connection which corresponds most to the most primitive condition is the mesial edge which may therefore be identified with the original anterior trigonid crest. It seems to me to be very probable that both distal bridges, namely the second and third one, are of secondary nature, a possibility already considered by Remane. *Parapithecus* which by the majority of authors is regarded to be the most primitive anthropoid does not reveal any distinct direct connection between its conically formed protoconid and metaconid. A bridge is feigned here by these cusps located so closely together as to cause their convexities to be in direct contact for a long way. The conditions in modern gibbon (fig. 160) give a good idea of the original arrangement of the cusps. These facts also shed some light on the peculiar feature of the trigonid area in *Sinanthropus* molars. I am inclined to consider the triangular area and the absence of any direct connection between the protoconid and metaconid as the real primitive stage as far as anthropoids are concerned, and the presence of one or two bridges merely as secondary acquisitions in spite of their occupying the region in which the persistence of the distal trigonid crest could be expected. This opinion is confirmed by the special formations of those bridges in the molars of *Dryopithecus*, *Australopithecus* and fossil orang in which they represent only coarse wrinkles on the slopes of the cusps concerned. The third bridge identified by Remane as the distal trigonid crest is in any case a secondary formation and thus is in no way connected with that special structure.

When comparing the *Sinanthropus* molars with those of recent man (figs. 143, 162, 169, 293) the difference which strikes the eye first is the disproportion apparent in recent man between the stoutness of the crown and the root, with the former being relatively large and stout and the root small and feeble, while in *Sinanthropus* the latter at least shows the same degree of development in all dimensions or may even be stronger than the crown (compare figs. 139 with 143 or 162 with 142). As has been described above the crown itself in recent man is high in relation to its length and breadth. There is no cingulum, neither is there any indication of its differentiations even though the fissures separating the cusps are well developed on the buccal surface. The stronger convexity of the latter when compared with the lingual surface apparently must be considered to be the last remnant of that structure. The most characteristic differences, however, concern the chewing surface. Being unable to discuss here all its possible variations, the reader is referred to the publications of de Terra (1905), Adloff (1908), Bolk (1914), de Jonge-Cohen (1920), Lenhossek (1922), Gregory and Hellman (1926) and Hellman (1928). The cases illustrated in figures 143, *o*; 162, *o*; and 169, the first two of which represent copies from Lenhossek's types which he considered as specific for first and second molars at least of recent Europeans, reveal the essential features. As to the number of the cusps there is clearly a tendency in recent man to reduce the number of cusps from six or five to only four (figs. 152 and 169). Connected with this process is the decrease of the trigonid in length as well as in breadth and the increase of the talonid with the result that the latter becomes prevalent or at least equal in size. The length of the entire molar has thereby become shortened and its oblong shape changed into a quadratic one. Of the cusps the mesoconid is the first to be affected and has been lost completely in the quadratic type due to its assimilation by the hypoconid. The metaconid also undergoes a considerable decrease in size, so that it becomes equal to the protoconid. As a consequence of these changes the original *Dryopithecus* pattern is finally replaced by a cross pattern with quite a symmetrical arrangement of the four remaining cusps which, all having acquired the same size, are placed exactly opposite each other in longitudinal as well as transversal directions. Gregory and Hellman (1926) called this arrangement which is typical for recent man the "plus" pattern. But even in the plus pattern the metaconid may be in contact with the hypoconid by means of a narrow wrinkle crossing the intersection of those furrows seemingly characteristic for the molars of the Neanderthal group (see below).

Since we are dealing with a progressive process of reduction taking place in recent man, its different stages may still be recognized. Hellman (1928) distinguishes four phases: Phase I exhibits the typical *Dryopithecus* pattern, in phase II the furrow separating the mesoconid from the hypoconid has been lost whereas the remainder of the pattern is unchanged, in phase III the metaconid is so reduced in size that this cusp is no longer in contact with the hypoconid even though five cusps may still be present, and finally phase IV in which the typical cross form is represented, that is to say, the "plus pattern" with only four cusps. The first molar is the least affected by this process of reduction and the second the most. Moreover, there are great racial differences in the frequency of their occurrence which are of special interest with regard to the phylogenetic significance of the reduction in question. The following figures were taken from Hellman's tables. They show the percentages of phases I and IV for each molar and for individual races.

TABLE XX

		White ♂	Mongols (Buriats) ♂	West African Negroes
Phase I:	M_1	87	100	99
	M_2	—	—	17
	M_3	4	—	20
Phase IV:	M_1	4	—	—
	M_2	94	64	63
	M_3	62	23	17

It follows from these figures that the first molar has preserved the original pattern best but nevertheless already shows the beginning of a reduction, at least in the white races. The second molar is affected most as far as the white races are concerned where almost all teeth show the plus pattern, while in Negroes and Mongols the percentage of the plus pattern, although quite high, is much lower than in the Whites. Within the Mongol groups the reduction of M_2 is greatest in the Chinese (81% plus pattern), while the Eskimo show the lowest figure (50%). As regards Negroes and Australians it is worthy of note that the American Negroes exhibit a lower percentage of the plus pattern in M_2 (49%) than the Australians (52%). The first molar has preserved the *Dryopithecus* pattern in all these cases, with the exception of the Eskimos and American Negroes where there is a slight decrease (97% and 98%). The peculiarity that the plus pattern (phase IV) is less frequent in M_3 may depend upon the fact that the third molar is, as a whole, much more reduced in size than the second one and that the pattern itself is very irregular (see below).

Hellman's figures for the first molar are somewhat in contrast to Bolk's (1914) statement. Bolk claimed to have found a combination of four cusps in all three molars in 13.9% of his European material. For the second molar of Chinese Montelius (1933) also arrived at different figures from those of Hellman; he found five cusps in 56% and Sullivan (1920) arrived at 76.8% for Tarascan Indians. The cause for such discrepancies, although irrelevant to the problem, is that Hellman refers to the arrangement of the furrows and the other authors to the number of the cusps which, of course, is not quite exactly the same.

On the other hand six cusps have also been observed in recent man but they seem to be extremely rare (cf. de Terra, 1905 and de Jonge-Cohen, 1920) and concern almost exclusively the third molar which should better be left out of consideration on account of its irregularity in general. Such a well developed "tubercle 6" is present in the first molar of a Japanese child illustrated in figure 293. This sixth cusp occupies as in all other related cases the same place as in *Sinanthropus*.

Another peculiarity characteristic for recent man is the smoothness of the chewing surface. The inner slopes of the single cusps generally show only a faint elevation along their middle axis coursing from the tip to the crossing point of the main furrows but there are no distinct accessory ridges either in germs (fig. 169) or in freshly erupted teeth (figs. 143, o; 162, o). There are very important exceptions, however, which unfortunately have hitherto not been given sufficient attention. In some cases of recent man (see below chapter on wrinkles) the wrinkles are very marked, resembling in all their details those of *Sinanthropus* to such an extent that no differences can be found to exist between these two in this respect. Figure 170, *a* and *b*, represent two molars of palæolithic man of the "Upper Cave" of Choukoutien and figure 171 the first molar of a prehistoric Northern Chinese (No. 157). Whether the wrinkles are actually more pronounced in palæolithic man than in a more modern man as suggested by these type specimens is impossible to ascertain because of the insufficiency in material of the first mentioned type. In regard to present man I gained the impression from the material at my disposal that in teeth of Chinese, Japanese and Malayans the wrinkles are much more numerous and much more developed than in white races. Thus, it should prove to be of interest to make more extensive investigations in order to be able to decide as to how much of this presupposition is correct. In the case of the first molar of a Japanese child illustrated in figure 293, for instance, there are some characteristic wrinkles.

As already mentioned above the roots of the molars of recent man are very feeble when compared with those of *Sinanthropus* (figs. 143, 162). This is especially true for the two branches which taper off from the stem to the apex. As a rule both branches are equal in height and development and more or less curved toward each other. The mesial branch occasionally ends with two tips. It is interesting to note that in recent man the enamel also descends deeper on the buccal surface of the stem than on the lingual but the difference is not as pronounced as in *Sinanthropus*. However, the variation outlined for the number and arrangement of the cusps and the abundance and development of the wrinkles also applies to the appearance of the root. In some cases the root is as strong in relation to the robustness of the crown as in *Sinanthropus* and its distal branch is at the same time somewhat higher, longer and straighter than the mesial one. In figure 146 there are illustrated three first molars showing these features: *a* is the tooth of the Palæolithic man of the "Upper Cave" of Choukoutien; *b* pertains to recent Australian Aboriginal and *c* to a recent Eskimo, all three probably belonging to female individuals (compare fig. 142).

Crown as well as root of the lower molar of recent man show with undoubted certainty that they have to be traced back to the *Sinanthropus* molars. They represent a very simplified and reduced type of the former. Their smoothness and plain pattern, therefore, is in no way a primitive one as some authors believe, but rather a secondarily acquired pattern in the course of evolution. The correctness of such an interpretation is proven by two facts: first, the occurrence of variations in the general details of features in *Sinanthropus* on the one hand and those of recent man on the other which almost form a continuous line linking one type with the other; second, the conditions of the molars of the Neanderthal group. The general opinion is that the molars within this group are so recent human-like that there should practically be no essential difference. This judgement was based in particular on the appearance of the molars of the Heidelberg and Spy mandibles. Unfortunately, especially these teeth are so worn that only their general characters may be discerned. As to the Heidelberg mandible (fig. 301, *d*) the first molar is almost as broad as long (index—see below—after Schoetensack 96,6) but more important is the fact that the trigonid is narrower than the talonid. All three molars have five cusps. However, there is no indication of the presence of a real

Dryopithecus pattern but in its place there may be observed a "plus pattern" which corresponds to Hellman's phase III as figure 152 reveals, that is to say, the metaconid shows the same size as the protoconid. Nevertheless, the metaconid is in contact here with the hypoconid by means of a special wrinkle crossing the intersection of the furrows descrived above in the case of *Sinanthropus* molar of figure 147, *o*. As to the wrinkles, the special pattern of the furrows (fig. 152) seems to indicate that some accessory ridges must have been present. On the other hand there is no indication of a cingulum unless the deepened end of the outer furrow separating the protoconid from the hypoconid is taken as a faint remnant (see above). Essential differences from recent man with regard to the size or to the special appearance of the root cannot be found.

The molars of Krapina man are of special interest because they have been the object of a lengthy and vivid debate between Gorjanovic-Kramberger (1906, 1907, 1910) and Adloff (1907, 1908, 1909, 1910). The question concerning the special character of the roots of these molars will be discussed below in the chapter on "taurodontism." According to Gorjanovic-Kramberger (1907) the lower molars of Krapina are characterized as primitive by the following peculiarities:

1. the presence of four and one half cusps in M_3 in a very high percentage;
2. the presence of wrinkles;
3. the presence of a closed fissure (fovea anterior) in the trigonid region;
4. the direct continuation of the buccal furrow separating the protoconid and hypoconid in the corresponding furrow of the root.

Gorjanovic-Kramberger gave the following results for the first occurrence:

	5 cusps	4 cusps	4½ cusps
M_1	75%	c. 8%	17%
M_2	9%	45.5%	45.5%
M_3	variable	—	—

By the term 4½ cusps that author understood that a mesoconid is present but more or less reduced in size, so that the molars within this group also practically possess five cusps. This means that in 45.5% five cusps are discernible instead of four. As is revealed by the corresponding figures for recent man given above, there actually is a difference only between Krapina and modern European but none between the former and other races (Chinese 56% after Montelius, Tarascan Indians 76.8%). Gorjanovic-Kramberger omitted to refer to the proportions of the crown and the arrangement of the cusps. But figure 150 representing a copy of the first molar considered as typical by him (G-Kr's Plate XIII, fig. 5) demonstrates that the trigonid is slightly broader than the talonid and that the metaconid has about the same size as the protoconid. The *Dryopithecus* pattern as far as the arrangement of the furrows is concerned has been lost but a wrinkle descending from the hypoconid is still in contact with a corresponding wrinkle of the metaconid. Apart from this, the wrinkles are very well developed and show such relations to the cusps which must be considered as being specific for anthropoids and *Sinanthropus*. The configuration of the mesial edge and adjoining parts has been described by Gorjanovic-Kramberger as closed fissure identical with the fovea anterior. Indeed, it corresponds perfectly to the feature of the *Sinanthropus* standard type I (compare fig. 165, *o*). The fourth peculiarity of the Krapina molar will be discussed below in connection with a similar feature in other Neanderthal molars.

As to the molars of the Mousterian youth Gregory (1922) stated that the *Dryopithecus* pattern undergoes a progressive obliteration proceeding from M_1 to M_3 although the plus pattern itself is not fully attained. In figures 154 the first (a) and the second (b) molars of this Neanderthal type are illustrated. As already noted by Gregory, it is also characteristic for these teeth that the trigonid is narrower than the talonid and the entire tooth—especially M_2—very broad in relation to its length. M_2 exhibits a clear plus pattern (Hellman's phase III), although five (perhaps even six) cusps are present, the metaconid being smaller than the protoconid but the metaconid still in contact with the hypoconid (see above). In M_1 the conditions are not so distinct on account of the relatively high degree of attrition; however the arrangement of the furrows led me to believe that six cusps may have been present. The area of the fovea anterior presents in both molars the same aspect as in the *Sinanthropus* molar of figure 163, that is to say, the fovea is represented by a deep transversal fissure bordered on its distal side by a ridge-like connection of the paraconid and protonid. Moreover, it is remarkable that the second molar is larger than the first.

The molars of the Ehringsdorf child (figs. 151 and 167) have been very thoroughly described by H. Virchow (1920). The second molar is like in the Mousterian youth larger than the first. In both molars there are five cusps and the trigonid is narrower than the talonid. The metaconid shows the same size as the protoconid, the former being wider, so that when superficially considered the plus pattern (phase III) seems to exist in both molars, but in both teeth there is a small projection of the hypoconid intercalating between the protoconid and entoconid and meeting the metaconid like in all other cases of the Neanderthal molars. Virchow called attention to the occurrence of a very minute cusp-like elevation within the groove separating the hypoconid from the mesoconid and present also in the Taubach molar (fig. 153, *o*). Although the second molar is rather worn there is no doubt that there must have been many wrinkles, the general and special arrangement of which was apparently similar to that in *Sinanthropus*. The configuration of the area of the fovea anterior is exactly the same as in the Mousterian molars. A cingulum is not clearly indicated; Virchow, however, reports that the buccal surface of the first molar is more curved than in recent man and projects bulb-like near the base of the crown.

The Taubach molar (fig. 153) described in detail by H. Virchow (1917) resembles according to that author the Ehringsdorf molars so close that it is not necessary to outline the single details here. As a comparison of figure 153 with 167 shows there are indeed no essential differences in any of the features. One fact, however, is worthy of note, namely, Nehring who first described that tooth (1895) called attention to some peculiarities on its buccal surface which he considered as specific anthropoid (chimpanzee) characters. Virchow found them also in the Ehringsdorf child. The features in question are a mesial and a distal furrow which cut in deeply between the protoconid and hypoconid (fig. 153, *b*) and the hypoconid and mesoconid, respectively, and fine stroke-like depressions on the mesial moiety of the buccal surface of the protoconid. The anterior furrow continues downwards toward the root and separates its stem also up to the point of bifurcation (fig. 153, *b*, *o*). This is apparently the same phenomenon as the one described by Gorjanovic-Kramberger characterizing the Krapina molar (see above, item 4). In *Sinanthropus* the peculiarities in question are typical and in some cases much more developed than in the Neanderthal molars as is evident in figure 139, *b*. As shown above, these features have to be considered as differentiations of the cingulum and the stylar cusps which frequently are particularly pronounced in the molars of gorilla (fig. 181). Nehring was correct in his assumption in so far that he considered these structures of the Taubach tooth as pithecoid, that is to say, chimpanzoid, but there are no other features which this tooth shares in common especially with the chimpanzee and thus represents a genuine Neanderthal molar.

The two molar germs, the first and second (figs. 149 and 168) embedded within the mandible of the Gibraltar child (compare Buxton, 1928) as a whole resemble very closely the other molars of the Neanderthal group despite some significant differences in certain details. Both molars not only have five well developed cusps but in M_1 the tubercle 6 is strikingly large. In addition, the trigonid of M_1 has about the same breadth as the talonid. The *Dryopithecus* pattern has been lost and replaced by a typical plus pattern conforming to Hellman's phase III, but in this case also there is a clear connection between the metaconid and the hypoconid by means of a wrinkle continuing from the latter cusp (fig. 149). In both cases the wrinkles are well developed and show all characteristic features. The configuration of the region of the fovea anterior here is also of special interest because both molars display the same pattern as the Mousterian and Ehringsdorf molars and thus resemble the *Sinanthropus* pattern of figure 163.

In all other cases of molars within the Neanderthal group the teeth are so worn that the special details are no longer discernible. According to Gorjanovic-Kramberger the first molars of the Spy mandible possess five cusps but the second and third only four.

As to the roots of the molars of the Neanderthal group there is no doubt that they are much weaker than in *Sinanthropus*. Even in the extraordinary robust Heidelberg mandible the roots of the molars (fig. 315) are much less developed than in *Sinanthropus* and in addition do not show the peculiarities characteristic for the latter (cf. problem on taurodontism below). While Gorjanovic-Kramberger (1910) and H. Virchow (1920) describe the branches of the roots as being in parallel position Adloff (1909) contends that they diverge, a statement which is not quite correct (compare fig. 315 and Schoetensack's plate 9, fig. 32). The roots of the Krapina molars, in so far as they do not represent the so-called prismatic root (see below), do not differ from those of recent man when taking Gorjanovic-Kramberger's skiagrams (1910, plate 3, figs. 2 and 3) for comparison. In one case (M_1 G.-Kr.'s fig. 3) the distal root is straight and considerably longer than the mesial one as may also occur occasionally in recent man (see above). The molar roots of La Quina show, according to H. Martin's skiagram (reproduced here as figure 237) no essential differences from those of recent man, except again the taurodontism. H. Martin (1923) himself remarks, however, that the mesial branch of M_1 is lower than the distal one and that the mesial branch of M_2 is again subdivided into two small branches. The roots of the molars of the adult Ehringsdorf mandible present, as H. Virchow (1920) himself had noted, a pithecoid aspect with the distal branch being in straight line, while the mesial one slightly curved toward the tip of the former, but the skiagram reproduced here as figure 238 fails to confirm this observation.

The preceding estimation of the molars within the Neanderthal group shows that they hardly differ essentially from those of recent man in regard to such features which characterize the *Sinanthropus* molars. The only essential difference consists of the abundance of the wrinkles in the former but even this is not at all a fundamental one, because molars with well developed wrinkles are not infrequently found even in recent man (see above). On the other hand some variations in the appearance of the Neanderthal molars link recent man with *Sinanthropus* as corresponding variations also occur in the latter, for instance the presence of six cusps and their arrangement, especially the connection between the metaconid and the hypoconid in spite of the existence of a plus pattern, the special configuration of the region of the fossa anterior, the indication of a cingulum manifested by the relief of the buccal surface and the differences between the mesial and distal branches of the root. The most specific peculiarities of the *Sinanthropus* molars, however, are entirely absent in the molars of the Neanderthal group, and this fact proves that the former is much more primitive and much closer related to the anthropoids than the latter. Other related questions will be dealt with below.

Third molar (figs. 172-177, 180, 283-285, 287, 289, 295, 296, 340).

The third lower molar of recent man is a very characteristic tooth because of its great variability which makes a precise definition of its typical features rather difficult. Since such an inconstancy is also true for *Sinanthropus* to a certain extent, it facilitates the determination of a given molar as being the third one when found as an isolated tooth.

In the material at our disposal there are four molars *in situ* (figs. 172, 173, 174, 175, 180, 283-285) and six isolated, that is a total of ten molars. Most of these are more or less worn but three are completely intact with two representing germs (figs. 176 and 177) and one (fig. 340) an immature tooth which has just erupted. As to the sex, six or seven molars represent the large type and therefore must be considered as probably belonging to male individuals, and the remaining ones to female.

Like in the other two molars the crown is very low in relation to its length (fig. 340, *b*, *l*) and breadth and as is true of the other, the buccal surface strongly sways in lingual direction (figs. 177, *m*, *d*, *o*; 180; 340, *o*) much more than the lingual surface towards the opposite direction. This condition produces a bulbous projection of the basal part of that surface which must be taken to represent the remnant of a cingulum (compare fig. 180 M_3 with fig. 181). The existence of the cingulum furthermore is manifested by the development of the S-curved indentation described above as characteristic for the first and second molars. This feature is in some cases more pronounced on the buccal surface of the protoconid (fig. 176), in other more on that of the hypoconid (figs. 172 (280) and 177). In all cases, however, the furrows separating the cusps in question on this side are very deeply impressed ending downward in a fine pit and diverging upwards so that the entire feature resembles that of stylar cusps. In the molar illustrated in figure 340, *b* the furrows on both sides of the hypoconid show this peculiarity very distinctly. The cusps are well developed, the buccal ones being slightly higher than the lingual. Their number varies: in the case of figure 340 there are five cusps; but in contrast to the typical feature in the other molars the *protoconid* is by far the largest cusp: the metaconid is very small and of about the same size as the mesoconid; the entoconid is very long; whether its distal portion which is separated from the main part by a distinct depression and provided with a special tip (*l*) is to be considered as equivalent to a sixth tubercle is difficult to say. The pattern formed by these cusps is neither a *Dryopithecus* pattern nor a plus pattern because of the extensive contact between protoconid and entoconid. All cusps are covered by wrinkles in their characteristic arrangement. The region of the fovea anterior shows, excluding the mesial edge, only one strong wrinkle on the buccal side but there is no special elevation on the lingual one. The crown is oval with the trigonid narrower than the talonid.

In contrast to this molar the one presented in figure 176, *o* (295) offers quite a different aspect in regard to the shape of the crown and the pattern of the chewing surface. The tooth is almost quadratic with the angles rounded off; the trigonid slightly broader than the talonid occupies a much larger area than the latter. There are only four cusps, with the mesoconid missing altogether. The metaconid is by far the largest cusp, almost as large as the protoconid plus the hypoconid, while the entoconid is represented only by a separated minute tubercle. The cusps are not high but well developed and covered by abundant wrinkles at their typical location. The configuration of the region of the fovea anterior is the same as in the first and second molars described above as characteristic, that is to say, only the mesial edge is developed while a real fossa is absent. There is a typical *Dryopithecus* pattern even though there are only four cusps present.

The molar presented in figure 177, *o* resembles the one just described very closely with regard to the general shape of the crown, the abundance of wrinkles and the configuration of the region of the fovea anterior. But there are some interesting differences, namely the trigonid is slightly narrower and shorter than the talonid, the metaconid is of the same size as the protoconid and the hypoconid is like the entoconid; in addition a small mesoconid is present. Furthermore, it shows a typical plus pattern (Hellman's phase IV).

The remaining molars among our collection, more or less worn, range between one extreme such as is represented by molar in figure 340 and the other in figure 177. In the cases illustrated in figures 173, *b*; 174, 175 and the recently recovered molar No. 136′ (not illustrated) the trigonid is clearly broader than the talonid, with the teeth getting narrower toward their rounded off distal ends. As much as can be judged from the arrangements of the furrows, if not completely affected by attrition, there have been five cusps present in all these molars and also in the molar No. 134′ (not illustrated). But the special patterns vary. In this regard figure 173, *b* corresponds to figure 176, figure 175 to figure 177, the molar No. 134′ and 136′ to figure 340; the pattern of figure 174 indicates the protoconid and metaconid being of the same size and the *mesoconid* present. A typical *Dryopithecus* pattern does not exist in any of those cases, the metaconid corresponding in size to the protoconid or being even smaller. Therefore the prevalent pattern is the plus pattern. In all instances, however, there must have existed a great abundance of wrinkles. Besides, the characteristic differentiation of the cingulum is likewise indicated in all cases (cf. figs. 173, 174).

The roots of all the third molars in our collection in so far as they are sufficiently developed show a distinct tendency towards fusion. The root illustrated in figure 172 represents the least advanced stage with the mesial and distal branches still partly separated and distinguishable as such by deep furrows which are more marked on the lingual surface than on the buccal one. Like in the entirely separated branches the mesial branch is much thicker (m) than the distal one (d) and terminates into two distinct tips. Figure 173, *a*, shows the arrangement of these branches viewed from below. The whole root is slightly bent distalwards. In the neck region there is only a slight constriction (compare also fig. 180). The immature root represented in figure 340 is much more fused than that in the former case, the primary division being indicated only by a deep furrow on the lingual side (l). In this case the crown is in all dimensions larger than the neck of the root and the entire root is strongly bent distalwards. In molars No. 134′ there are longitudinal furrows on the buccal and lingual side and in the molar No. 136′ as in figure 340 only one on the latter side. In both these cases there is only one blunt tip with very slight impressions representing the end of the corresponding furrows.

TABLE XXI

Measurements of third lower molars

		Molars in situ				Isolated molars						
		172:173	174	175:293		176:295	177:296		340			
		289 No. *114* a. ♀ 181 257 3[illegible]	No. *115* ♂.	285 No. *116* ♂ G[illegible]	No. *117* ♀	No. 50 ♂	No. 51 ♀ x	No. 52 ♂	No. 131′ ♂?	No. 134′ ♂.	No. 136′ ♂	Average
crown	height	(3.8)	(6.0)	(4.8)	—	(5.3)	7.0	6.7	7.0	(5.0)	(4.3)	6.9
	length	10.0	12.9	12.0	10.0	13.8	12.2	12.2	12.7	10.6	10.9	*11.7*
	breadth	10.0	12.4	12.3	10.2	11.8?	12.1	11.4	10.8	10.7	10.8	*11.2*
	length-breadth index	100.0	96.1	100.0	102.0	85.6?	99.4	93.6	85.3	100.6	99.2	96.2
	trigonid breadth	10.0	12.4	12.3	—	11.8	12.1	11.4	10.3	10.7	10.8	*11.3*
	talonid breadth	9.3	12.1	11.6	—	—	11.7	11.5	10.8	10.6	10.8	*11.0*
	trigonid index	100.0	96.1	100.0	—	85.6?	99.4	93.6	84.5	100.6	99.2	96.6
	talonid index	93.0	93.8	94.4	—	—	96.7	94.4	85.3	100.0	99.2	94.2
root	height	11.6	—	15.5	—	—	—	—	—	13.0	13.6	
	length	8.7	11.4	11.3	—	—	—	—	10.1	8.1	9.1	
	breadth	8.6	10.7	10.0	—	—	—	—	9.1	8.6	9.9	

Form and size of the third lower molar also show a great variability in anthropoids. In gorilla the tooth is mostly larger (longer and broader) than the second molar as is evident from the three molars in figure 297. But there are also cases in which the third molar is the smallest, even smaller than the first one. The extent of the variation in form and size is revealed by the six third molars given by Remane (1921) as figure 7 *a-f*. All teeth there, with the exception of one, have in common that the trigonid is broader than the talonid, the latter part being rounded off toward the distal end, so that the form of the tooth more or less becomes triangular. Occasionally however the molar may be quadratic with all angles rounded off. In the number and size of the cusps there is no distinct difference between the third and the other molars. If the tooth is reduced in size, then all cusps are

x upper molar.
Robinson p. 56.

proportionately reduced. The mesoconid which occupies the middle line in the first molar has shifted buccalward. Nevertheless, the *Dryopithecus* pattern may become indistinct and the metaconid be of the same length as the protoconid.

In chimpanzee (compare Remane's figure 8) the variation of size and form of the third molar is the same as in gorilla with the quadratic types prevailing in the former; the trigonid is only slightly broader than the talonid or of about the same breadth as the latter. A *Dryopithecus* pattern is absent, metaconid and protoconid being of the same size in most of the cases. The position of the metaconid is also variable.

In the orang (fig. 179) it is not so much the size but rather the form that constitutes the difference between the third and the other molars. The third molar may occasionally be elongated, decreasing at the same time distally in breadth so that the trigonid represents by far the broadest part of the tooth. The so produced triangular form is very characteristic for the third molar. In this respect there is no difference between fossil (fig. 179) and recent orang. The decrease of the talonid in breadth is due in particular to the reduction of the entoconid in its buccolingual diameter, while all five cusps are preserved. The *Dryopithecus* pattern may at times become indistinct because of the disappearance of the boundary between protoconid and entoconid.

As to the roots of the third molar of anthropoids there is no clear indication of a reduction or fusion. In the gorilla (fig. 318) the branches are lower than in the other molars but longer and further apart from each other; the same holds good for the orang given in figure 321, while in the orang presented as figure 320 both branches are curved inward. As Remane noted in chimpanzee and to a lesser extent also in orang the distal branch of the root is narrower and weaker than the mesial one. I failed to find any record of the occurrence of fused branches and its ratio to unfused ones in anthropoids.

Some third molars of *Dryopithecus* are also available for comparison. They are long, narrow and rounded off at the distal end, that is to say, they show the same feature as the elongated teeth of gorilla or orang. In other details they do not differ essentially from the first or second molars. The root which is partly preserved in the case illustrated by Branco (1898, plate 2, fig. 11) is divided into two branches the distal one of which is much stronger than the mesial like in the first molar of *Sinanthropus*.

The third molar of *Sinanthropus* when compared with that of the anthropoids seems to have in common with the latter the tendency toward variation of form and size, despite some significant differences. While in the anthropoids there is no indication of a reduction of the single cusps or a change in their arrangement and the mesoconid always present, *Sinanthropus* shows a tendency of limitating the mesoconid and reducing the size of the metaconid resulting in the replacement in most cases of the original *Dryopithecus* pattern by a plus pattern. In conjunction with this process there is a reduction of the root which is expressed by its tendency towards fusion and decrease in robustness, while in anthropoids the conditions of the root are not so different from those of the other molars. It may be that the great variability in form and size of the third molar of anthropoids must be considered as the beginning of a regressive process but even if this should be true, this process is much more pronounced in *Sinanthropus*.

The third lower molar of recent man shows a great variability which points in the direction of a reduction of the tooth. It is remarkable, however, that according to Lenhossek (1922), this regressive tendency is not as pronounced as in the upper third molar and that the variability is far less evident than in the latter. As a rule the third molar is smaller than the other molars but there are also cases in which it is the largest of all three. With respect to its form, it becomes narrower toward the distal end and is rounded off, that is to say, the trigonid is broader than the talonid. In most of the cases four cusps are present, the mesoconid having been lost. Protoconid and metaconid are the largest cusps with the former larger than the latter. According to Hillebrand (1908) four cusps are found in 60.7%, five cusps in 12% and 3 cusps in 6%, but de Terra's (1905) list shows a greater variation within the various races. The schema of Hellman's (1928) pattern does not correspond to the number of cusps (see above) inasmuch as the plain plus pattern is developed in only 62% of third molars against 94% in second ones. For phase III, however, in which the mesoconid is more or less preserved Hellman records the following:

	African Negro	American Negro	Australian Aboriginal
M_3	8%	24%	43%
M_1	59%	63%	72%

Occasionally the chewing surface is not formed by three to five distinct cusps but by dissociated cusps in an extensive number of small tubercles. As to the root partial fusion of the branches occur in 50% and complete division into two branches in 41%.

Because of this variability a comparison between *Sinanthropus* and recent man is not as easy as when dealing with the other molars. Lenhossek's illustration which I have made use of and reproduced as figure 178 cannot be considered as representing a typical third molar because of the existence of five well developed cusps and completely separated branches of the root. Certain differences, however, may be seen quite distinctly in this instance also, namely the disproportion between size of the crown and that of the root in recent man in contrast to the relative conformity of these two components of the tooth in *Sinanthropus* (fig. 172) and furthermore, the height of the crown in relation to its length and breadth in the former and its lowness in the latter. These differences are not specific for the third molar only but hold good also for the other molars (see above).

The ten third molars of *Sinanthropus* at our disposal are when compared with the first and second molars of *Sincnthropus* on the one hand and with the third molar of recent man on the other clearly less reduced as far as the crown is concerned but more in respect to the root. because the branches of all seven cases are more or less fused. Whether such conditions are characteristic for *Sinanthropus* or merely due to the scarcity of material is difficult to say.

The third molars of the Neanderthal group show the same variation in size and form which characterize this tooth in recent man. In the Heidelberg mandible (fig. 301, *d*; fig. 182) the third molar is smaller than the second and more quadratic while it is elongated distally in the Mousterian youth (fig. 185). In the Ehringsdorf adult both molars are reduced in size, that of the left side even to only a quarter of the original size. The molars of the Krapina man, however, do not exhibit such extreme degrees of reduction. With regard to the pattern of the chewing surface the Heidelberg molar (fig. 182) shows five cusps but with a reversed *Dryopithecus* pattern like the *Sinanthropus* molar in figure 340 with the enlarged protoconid in contact with the entoconid. The trigonid here is narrower than the talonid. In the Krapina molar illustrated in figure 183 the trigonid cusps are considerably increased in length at the expense of the talonid cusps; the protoconid at the same time becomes much larger than the metaconid. while in the Mousterian youth (fig. 185) the trigonid has the normal size but the talonid is considerably elongated distally. Despite the latter fact the trigonid here is not broader than the talonid. The cusps are partly recognizable in the Krapina molar and in that of the Mousterian youth but the longitudinal furrows separating protoconid and metaconid are overshadowed and the metaconid (Krapina) and the entoconid (Le Moustier) are dissociated in a great number of small tubercles which Lenhossek described as being characteristic for recent man (see above). Unfortunately. material of unworn third molars of the Neanderthal group is very scarce, so that additional examples are not available for comparison. The wrinkles as far as they are preserved show the same character as those of the other molars.

As to the roots of the third molars of the Neanderthal group there are two separated branches in the Heidelberg molar as may be observed in Schoetensack's skiagrams, in the Ehringsdorf adult the branches are fused according to Virchow's skiagram, whereas in the Krapina molars either fused or separated branches may occur (fig. 237).

All these facts prove that the molars of the Neanderthal group when taken as a whole resemble much closer those of recent man than those of *Sinanthropus*. The great variability of this molar already characteristic for the great apes, especially chimpanzee and orang, is also true for the hominids. There is no doubt, however, that it is much greater in recent man than in *Sinanthropus* and that the Neanderthal group is closer to recent man than to the latter.

If this variability is considered an indication of involution, the process is more advanced in recent and Neanderthal man than in *Sinanthropus*.

c. SIZE AND PROPORTION OF CROWNS OF THE THREE MOLARS

In recent man the first lower molar usually is the largest of the three molars (Hrdlicka, 1923) followed by the second and the third. In exceptional cases the third may be larger than the second or even the first. In anthropoids the second molar is the largest followed by the third and the first being the smallest. This sequence is the rule for gorilla and orang, while in chimpanzee occasionally, especially in female individuals, the first molar exceeds the third one in size (compare Remane's table X). As to how *Sinanthropus* behaves in this respect can, of course, only be ascertained on the basis of such cases in which the molars are still *in situ*. The figures derived from the respective measurements in Tables XVIII and XIX reveal that the average size of the first molars computed by their length × breadth is 149, while that of the second molar is 159. This implies that in *Sinanthropus* the second molar is slightly larger than the first one (compare also Diagr. I). The average size of the third molar amounts to 133 (Table XXI) which is distinctly less than that of the first one.

Hrdlicka (1924) on the basis of numerous measurements of molars of modern, palæolithic and Neanderthal man arrived at the conclusion that the relative length is greater the greater their antiquity, while the breadth only shows slight changes in the course of man's evolution. Thus, the molars of the forerunner of man should be longer but only slightly thicker than those of recent man. The ratio between length and breadth may be expressed by the length-breadth index: the lower the index the more the length predominates and *vice versa*. I rather doubt whether this index really is as significant as Hrdlicka believes it to be, because its value depends considerably upon the accidental conditions of the contact facets which influence the length but not the breadth (see above). On the other hand there is a great individual variation. As for instance Hrdlicka's list demonstrates, the index of M_1 ranges for the various first molars of Predmost from 85.3 to 97.1; for those of Krapina from 90.6 to 100.0. The list compiled by H. Virchow (1920) shows that the value of the index of M_1 of recent man ranges from 89.8 to 108.6 and those of the Ehringsdorf child and adult from 87.5 to 93.2. According to Table XVIII the length-breadth index of M_1 of *Sinanthropus* ranges from 91.1 to 97.2 for the teeth *in situ* and from 89.4 to 102.0 for the entire material, with the result that the index for the *Sinanthropus* molar is higher than even that for Predmost and completely falls within the range of recent man. The average index for M_1 of recent man which I computed on the basis of Hrdlicka's (1923) results is 96.8, while de Terra's figures (1905) yield an average index of 93.8 for the same group. The corresponding average index of the whole *Sinanthropus* material is 93.3. For the great apes I computed the average index of the first molar with the aid of Remane's (1921) figures which are: gorilla (♂ and ♀) 87.7; chimpanzee (♂ and ♀) 88.8, orang (♂ and ♀) 94.6; all three combined 90.0. The average index for the Krapina first molars is 94.0. Cases of hominids in which only one or two molars are available (Heidelberg, Le Moustier, etc.) cannot be used for such a comparison. With every reservation as to the reliability of the following figures the order of the indices for all three molars would be as follows:

TABLE XXII

Length-breadth indices

M_1		M_2		M_3	
Anthropoids	90.0	Anthropoids	92.5	Krapina	91.2
Predmost	91.7	Krapina	92.7	Anthropoids	92.4
Sinanthropus	93.3	Predmost	95.8	Predmost	93.7
Krapina	94.0	*Sinanthropus*	96.8	*Sinanthropus*	96.2
Recent man	93.8-96.8	Recent man	93.9-97.7	Recent man	96.8

Within the anthropoids the indices of the second and third molars of the chimpanzee amounting to 96.1 and 97.3, respectively, exceed the corresponding indices of all hominid groups and the same is true of the first molar of orang with an index of 94.6 (compare Table XXII). These figures do not support Hrdlicka's assumption.

H. Virchow (1920) in finding that the second molar is longer than the first in the Ehringsdorf man (child and adult) is inclined to consider this peculiarity as a pithecoid character. If the length of the second molar is expressed in percentage of the length of the first one and computed on the basis of the corresponding values given by the various authors, then we arrive at the following figures:

TABLE XXIII

Length of M_2 in percentage of M_1

Recent man	96.8 (de Terra)
Spy II	98.0 (Schoetensack)
Sinanthropus	100.0 (molars *in situ*)
Spy I	100.0 (Schoetensack)
Chimpanzee ♂	100.4 (Remane)
La Quina	100.3 (H. Martin)
Krapina	103.6 (only the molars *in situ*; Gorjanovic-Kramberger)
Chimpanzee ♀	104.2 (Remane)
Orang ♀	104.5 "
Le Moustier	105.8 (H. Virchow)
Gorilla ♀	108.8 (Remane)
Ehringsdorf	109.3 (H. Virchow)
Heidelberg	109.4 (Schoetensack)
Gorilla ♂	110.9 (Remane)

It is apparent from these figures that *Sinanthropus* ranges between recent man on the one side and the male chimpanzee on the other, while the molars of Krapina, Ehringsdorf and Heidelberg show a much higher index and like that of the male gorilla. It should be borne in mind, however, that in the cases of the Heidelberg and Ehringsdorf only one and two specimens of each type are available, while of *Sinanthropus* there are seven first and six second molars *in situ*.

Of more importance than the relations between length and breadth and the differences between first, second and third molars in this respect are the differences in breadth between the trigonid and the talonid. Gregory and Hellman (1926) who called special attention to these differences, proposed to determine the values concerned by computing the trigonid and talonid indices, that is the breadth of the trigonid and talonid, respectively, expressed in percentage of the length of the entire tooth. If the trigonid is broader than the talonid, the index of the former will be higher than that of the latter and *vice versa*. A trigonid exceeding the talonid in breadth must be considered a primitive character since the latter formation in the course of evolution of the mammalian molars appears as a secondary acquisition. Gregory and Hellman setting out from the respective conditions existing in *Dryopithecus*, have computed the trigonid and talonid indices of all three molars of anthropoids, fossil hominids and recent man. It follows from their results that as far as *Dryopithecus* and recent anthropoids are concerned the trigonid is generally broader by some units than the talonid, but occasionally the talonid may also be broader than the trigonid. Such a condition may even be found in one and the same individual with the molar of one side showing a broader trigonid, while that of the other exhibits a broader talonid. Thus the index in question is only of significance when applied as a criterion for an entire given group but it is without value as a diagonistic aid in individual cases. According to Gregory and Hellman the talonid of the first molar in recent man is generally broader than the trigonid, while in the second and third molars the latter is in the majority of cases—quoted by those authors—broader than the talonid. It appears that racial differences are irrelevant in this respect. In *Sinanthropus* the indices computed from the average figures (compare Tables XVIII, XIX, XXI) are:

	M_1	M_2	M_3
trigonid index	96.8 (94.5)	98.4 (95.3)	96.6
talonid index	90.8 (90.8)	98.3 (94.5)	94.2

The first indices of M_1 and M_2 refer to the molars *in situ*, while those in brackets are for all molars available (*in situ* and isolated combined). In the case of M_3 such a discrimination is not necessary because this molar is determinable with approximate certainty even when isolated.

As these indices show, the trigonid in all three molars of *Sinanthropus* is broader than the talonid, the difference being greatest in the first molar and smallest in the second. Among the eight first molars of our collection in which both indices are computable there is not one case in which the talonid is broader than the trigonid, while among the eight second molars there is one instance and two in the series of the eight third molars in which the talonid is broader, but the differences are only slight. With reference to fossil hominids Gregory and Hellman only quote the molars of Heidelberg, Ehringsdorf and Le Moustier as given in Table XXIV.

TABLE XXIV

	Heidelberg			Ehringsdorf					Le Moustier	
				child		adult				
	M_1	M_2	M_3	M_1	M_2	M_1	M_2	M_3	M_1	M_2
trigonid index	94	86.2	93.0	86.6	78.1	91.0	87.2	91.3	84; 82	89.4; 85.7
talonid index	97	90.6	91.1	86.6	82.0	91.0	89.7	83.5	92; 88	86.9; 87.2

In all these cases the talonid is broader than the trigonid, except in M_3 of Heidelberg and Ehringsdorf and in the left M_2 of Le Moustier. The indices show that the *Sinanthropus* molars are in this respect also much more primitive than the molars of the Heidelberg and Ehringsdorf mandibles and those of the Mousterian youth.

The trigonid and talonid indices of two further specimens are of particular interest, namely those of the Piltdown molars and those of *Australopithecus* Dart. Gregory and Hellman computed the following values:

	Piltdown mandible		isolated tooth
	M_1	M_2	M_1
trigonid index	86.2	85.6	85.7
talonid index	78.0	81.6	80.0

For *Australopithecus* W. Abel (1931) gives the following indices:

	M_1	
	left	right
trigonid index	83.5	88.0
tolonid index	87.8	90.1

The talonid in the first molar of *Australopithecus* is also broader than the trigonid. W. Abel is inclined to consider this condition as an indication of advanced specialization of the entire type. Considering the fact, however, that the very same conditions have occasionally been found in the first molar of *Dryopithecus*, orang and chimpanzee of today, I doubt whether such a generalization based on a single occurrence is justified. I shall return to the problems on Piltdown and *Australopithecus* below.

d. PROBLEMS CONCERNING MOLARS IN GENERAL

In this section we deal with two special phenomena characteristic for all upper and lower molar of *Sinanthropus*, namely the so-called wrinkles and "taurodontism." The appearance and arrangement of wrinkles have already been described earlier in this study, thus we shall be concerned here only with the discusion of their diagnostic and taxonomic value. With regard to taurodontism the entire problem will be dealt with herein, especially in respect to the contention of certain authors that this feature is to be considered as a typical and irreversible specialization.

The wrinkles

The chewing surface of mammalian molars in some orders is not only equipped with cusps but also with more or less developed special ridges and furrows covering the entire surface. As their abundance and arrangement in no case show the same constancy as the cusps, most of the authors failed to attach great importance to this formation. More than this, their presence and special appearance have been neglected or, according to the standpoint of the respective author, minimized or contested. Hence, even recognized authorities in the field of odontology failed to determine the feature in question as an essential peculiarity characterizing anthropoids as well as hominids.

In 1887 Schlosser called attention to the fact that the molars of *Dryopithecus* (compare fig. 159) exhibit wrinkles similar to those of chimpanzee, orang and recent man, although much less developed than in these anthropoids. Schlosser believed that the wrinkles occurred for the first time within the anthropoid group in *Dryopithecus* and gradually increased in the course of evolution. However, since these wrinkles were very poor in man, he could not be a direct descendant from *Dryopithecus*, for in that case the wrinkles should be much more pronounced in recent man than in recent anthropoids. Although Schlosser's deduction is incorrect in so far as *Sinanthropus* and Neanderthal man have the wrinkles really much more developed than recent man, his line of thought is interesting because he used that feature as a criterion for classification. He did the same later (1907) when he rejected the possibility that Tarsius could have been derived from the fossil *Tarsioidea Washakius* because of the latter having wrinkled molars and the former not.

It follows from Schlosser's description that wrinkles are not only found in fossil and recent anthropoids but also in fossil prosimians (Washakius and Necrolemur). According to Branco (1898) and Bolk (1914) they also occur in lower molars of recent platyrrhine monkeys, for instance in Pithecia, the pattern of which is reproduced by Branco and copied here in figure 184. The occurrence of wrinkles, however, is not at all confined to Pithecia. I found them to be present in the permanent and deciduous lower molars of Alouatta, Mycetes and Callithrix, so that it may be supposed that the existence of wrinkles is rather diffused within the group of Platyrrhinæ. However, the appearance and the arrangement of these wrinkles differ very characteristically from those of anthropoids (fig. 184). They represent low and regular convolutions which occupy not so much the inner slopes of the cusps or the declivity of the elevated border surrounding the chewing surface as the cavity proper of this surface. In addition, they also cover the outer slopes of the trigonid cusps. In both respects the wrinkles resemble closely the conditions of the molars of the carnivores, although here again their appearance and arrangement are quite different from those of the lower primates and anthropoids.

Thus, it is not sufficient just to determine the mere presence of wrinkles for the purpose of classification but also to define their special character. In this respect there is no doubt that wrinkles occurring in fossil and recent anthropoids on one hand and in hominids on the other are identical formations. As has been shown earlier, they differ, it is true, in abundance and degree of development within the anthropoid groups themselves but their general appearance, their restriction to cusps and their arrangement are the same in all types of anthropoids and hominids (compare fig. 155). In this regard it is significant that even in gorilla with very fine and relatively low wrinkles and of rare occurrence there are races with well developed structures as for instance in *Gorilla beringei* (Adloff, 1908). I likewise have the impression that the wrinkles in the fossil orang are less abundant but coarser than in recent species of this anthropoid (fig. 243, *a*, *b*).

Selenka (1899) believed that there must be some connection between the development of wrinkles and the character of the cusps so that whenever the wrinkles are less abundant the cusps are high or the reverse. This assertion may be applicable if the gorilla with high cusps and few and fine wrinkles is compared with the orang with low cusps and very abundant wrinkles. However, if *Sinanthropus* with very pronounced wrinkles is compared with recent man in whom the wrinkles have almost disappeared completely and in whom the cusps are rather higher than in the former, then the correctness of the above mentioned conception becomes doubtful.

Although Branco predicted as early as 1898 that the ancestors of recent man must have been equipped with better developed wrinkles, yet it was not confirmed until the discovery of Krapina man the molars of whom have been found to be covered with characteristic wrinkles. Gorjanovic-Kramberger (1906) described them in great detail and showed their general arrangement by some excellent drawings (his figure 43, p. 205). He came to the conclusion (1907) that these wrinkles have been generally present in the Neanderthal group of fossil man, while in recent man they were lost. Since the wrinkles occur in similar conditions in recent anthropoids, that author considered those features to be pithecoid and primitive characteristics of the hominid.

It is strange that such a simple and easily demonstrable fact could be the subject of controversy for more than thirty years. The first to contend Gorjanovic-Kramberger's statement was de Terra (1905). This author believed that the formation of wrinkles should be considered to be only the expression of a general tendency to increase the chewing surface of the molars and if found in anthropoids merely a convergency without any phylogenetic significance. de Terra at least acknowledged the actual existence of wrinkles in anthropoids and hominids, whereas Adloff in denying any direct relation between both groups attempted in a great number of publications (1907-1937) to minimize the existence of wrinkles in hominids and thereby lower their general significance. Because of this author's most recent paper (1937) in which he deals with *Sinanthropus* teeth on the basis of some of my earlier brief notes (1935, 1936a) I find it essential to enter into a new discussion of this problem at this time. In referring to the molars of *Sinanthropus* illustrated in the above mentioned publications and reproduced here as figs. 165, *o* and 290, Adloff claims that it may be seen at first sight that the wrinkles of the *Sinanthropus* molars were completely different from those of the anthropoids. Unfortunately, Adloff omitted to give any further explanation in support of this view and merely refers to future publications. In order to demonstrate that Adloff's opinion is without any foundation, it is sufficient to compare the *Sinanthropus* upper molar illustrated in figure 330 with that of a fossil orang in figures 332 and 336 or the *Sinanthropus* lower molars (figs. 163-166) with the lower molar of the fossil orang (fig. 243, *a*). Adloff points out in particular the molars of the Heidelberg and Ehringsdorf mandibles in an effort to prove that in these cases the wrinkles were not as abundant as in *Sinanthropus*. This, of course, is perfectly correct as has been mentioned above, but I fail to understand how this fact can be presented as a means of refuting the pithecoid character of the wrinkles. The Heidelberg molars have no wrinkles at all because they are worn (compare figs. 152, 182, 301, *d*) and the same is true of the molars of the Ehringsdorf adult. But the molars of the Ehringsdorf child have some typical wrinkles as may be observed in M_2 (fig. 167), while in M_1 (fig. 151) the wrinkles have become obliterated because of attrition. How great the differences can be in this respect may be judged by a comparison of an already functioning *Sinanthropus* M_1 with a M_2 just erupting (fig. 286). However aside from this, the wrinkles in the Heidelberg and Ehringsdorf molars like in those of other representatives of the Neanderthal group are much less developed than in *Sinanthropus* because these molars already represent a more advanced stage in the line leading to recent man. Adloff refers to the molars of the Mousterian youth, in whom the wrinkles were more developed so as to demonstrate the inconstant character of this feature. In reality, however, there is no difference in this respect between the M_3 of Le Moustier and that of the Ehringsdorf child (compare fig. 154, *b* with fig. 167). That the Mousterian M_3 (fig. 185) is equipped with a greater number of wrinkles is merely due to the fact that this tooth has just erupted and its wrinkles therefore not yet lost through attrition.

Another argument against the constant character of the wrinkles in hominid molars raised by Adloff (1937), although refuted by Aichel (1917) twenty years ago, is that the surface of the teeth which reveal wrinkles best in the stage as germs may become smooth in the course of a normal dental development. This argument is not any more convincing than the first one on account of the following facts: first, the wrinkles of the *Sinanthropus* teeth are not only present in germs embedded within the jaws but also in erupting or just erupted teeth (compare figs. 83, 101, 140, 163, 265, 286); second, in recent man the same is true in such races in which wrinkles still persist (figs. 170, *a*, *b*; 293) and third, in races of recent man in which the wrinkles are absent, they will neither be found in germs nor in erupting or in just erupted teeth. The lower premolars in figure 272, *d* and *c*, and in figure 273, *e*, furthermore the lower molar in figure 169, represent such specimens of immature teeth of recent man (European). Adloff believes that the irregularities of the enamel of germs represented by wrinkles may become smooth after the formation of Nasmyth's membrane. This, of course, is impossible because this membrane, a pellicle composed of dead cornified cells of the enamel organ, could never function in such a manner and, in addition, the membrane is formed long before the wrinkled teeth erupt. However apart from this, the wrinkles are not exclusively a formation of the enamel as Adloff suggests, for the dentine is also involved as was already recognized by Aichel (1917) and proven by R. Schwarz (1927) with the aid of cross sections through a lower molar of chimpanzee (his figure 410). That the same holds good for the *Sinanthropus* molars may be demonstrated by a transversal section of its crown (fig. 138) which shows that the superficial undulation of the enamel underlying the wrinkles is repeated in the same form by the surface of the dentine itself.

Adloff claims that the lower primates and the earliest anthropoids must have had smooth teeth and that the wrinkles therefore represented a relatively late specialization, probably acquired independently by the individual anthropoid genera. The first statement is incorrect. As shown above, wrinkles are already present in Eocene Tarsioidea, for instance in Necrolemur and *Washakius*. It seems to me that their presence is also indicated in the lower molars of *Adapis*. On the other hand, it is true that they are missing in certain early primates, but hitherto we have not been able to determine the real direct ancestors of either anthropoids or hominids. Thus, no claim can be made as to whether these groups derived from Eocene types were with or without wrinkles. The Miocene anthropoids like *Dryopithecus* have well developed wrinkles (fig. 159), the wrinkles being less abundant and coarser than those of recent anthropoids and therefore resemble quite closely the wrinkles of *Sinanthropus*. Whether *Dryopithecus* is to be considered a direct ancestor of the hominids as Gregory (1922) and O. Abel (1931) believe is irrelevant to the problem involving wrinkles. It may be that Adloff had *Parapithecus* in mind when considering the earliest anthropoids. It may also be possible that in this primate the wrinkles never existed and that *Parapithecus* nevertheless must be looked upon as an ancestor of the anthropoids. However, the absence of wrinkles in this case can in no case be used as an argument against the closer affinity of anthropoids and hominids if one admits, as Adloff himself does, that the recent anthropoids derived from *Parapithecus* have acquired the wrinkles subsequently. The essential point is that Adloff considers the alleged smoothness of human teeth a primitive feature and the complicated pattern of anthropoid teeth a proper specialization. Such a viewpoint was already contestable after the discovery of the Neanderthal teeth of Krapina, Ehringsdorf and Taubach but now in view of the *Sinanthropus* discoveries it has become entirely untenable.

To complete the survey of the various interpretations of wrinkles Aichel's viewpoint (1917) may be included. In contrast to Adloff and similar to de Terra this author believes that two independent types of molars should be distinguished, namely cuspidated and wrinkled ones. The latter type should be characteristic for anthropoids, the former for recent man, with no genetic connection between them. The wrinkled teeth occasionally met with in recent man should be considered as a completely new acquisition. Nevertheless, all hominid types in which they occur, that is the entire Neanderthal group and Late Palæolithic Man must be eliminated from the ancestry of recent man. Only the Heidelberg man the molars of whom Aichel strangely enough considers to have pure cuspidated cusps, although the teeth are almost completely worn off, is permitted to retain his place in this ancestry. That Aichel's strict discrimination between cuspidated and wrinkled teeth is a purely fictitious construction does not require any further elaboration as it is apparent even at a brief glance upon the molars of fossil and recent anthropoids and hominids. How far removed this author was from the reality when compiling his publication is further evident from the fact that he seriously claims that human molars with four cusps would represent the real primitive type, while molars with five cusps have to be considered as being of secondary nature.

At any rate, there is no doubt that wrinkles represent a characteristic feature of the *Sinanthropus* molar and that they disappear gradually in the course of human evolution: Neanderthal man—Late Palæolithic man—modern man. Their disappearance, however, is not yet complete for they are still to be found in many cases of present mankind, although mostly in a rather reduced form. This view first expressed by Gorjanovic-Kramberger (1906) on the basis of the Krapina findings proved to be correct. Virchow (1920), Lenhossek (1922) and Hrdlicka (1924) admit that wrinkles have a phylogenetic significance. de Terra's and Aichel's viewpoints as also Adloff's thus prove to be without any real foundation. Therefore, Gregory (1922) is fully justified in enumerating among the common characteristics of the teeth of anthropoids and hominids the following particularity: "Surface of enamel more or less furrowed and wrinkled." This statement does not only hold good for molars which most of the authors consider the only teeth equipped with wrinkles but also for premolars, and to a certain extent for canines, and especially for upper central incisors. As has been shown earlier when discussing these teeth of *Sinanthropus*, the pattern of their chewing or lingual surfaces, respectively, is characterized by accessory ridges and depressions between them the appearance of which corresponds entirely to the wrinkles of the molars. This pattern is the same in principle in anthropoids. It should not be overlooked that wrinkles represent only one of the numerous features linking anthropoids and hominids and that their elimination would in no way effect their close relationship.

"Taurodontism"

Keith (1913) in citing Adloff (1908) states that *in the modern mandible* the body of the tooth containing the pulp cavity is supra-alveolar and that only the roots are embedded in the mandible . . . . In passing from the first to the third molar the pulp cavity should tend to become embedded more and more within the alveolar process . . . . In the Heidelberg mandible the tendency as seen in the last molar of recent man should be exaggerated still more . . . . In all molars of the jaw the pulp cavity were large and the body of the tooth tends to be implanted in the alveolar border . . . . In the Krapina molars this tendency is so marked that the pulp cavity extends deeply into the region of the roots, the body of the tooth being enlarged at the expense of the roots. Keith found the same condition in ungulates and cud-chewing mammals, for instance in the ox, while in the carnivores the body of the tooth should occupy a supra-alveolar position. Keith therefore calls the first condition "taurodontism" and the second one "cynodontism." The Neanderthal man as represented by the Heidelberg and Krapina mandibles should show in contrast to recent man that "specialization" and thus have nothing in common with recent man. In his book "Antiquity of Man" (1925) Keith outlined his standpoint with more precision, laying greater stress upon the enlargement of the pulp cavity, however, than on the extension of the "body." In the Neanderthal group this cavity should extend toward the roots, the body being large and the roots short. As the primitive type of apes shows cynodontism and not taurodontism, recent man according to Keith resembles the original primate more than the Neanderthal man, hence the necessity of separating recent man and Neanderthal man genetically. Keith still holds this viewpoint. In his most recent paper (1937) he again states that the Western European Neanderthalers have to be excluded from the direct ancestry of modern man on account of their possession of certain specialized anatomical traits. Keith gives no further explanation but taurodontism in his opinion apparently must be considered as one of these peculiarities.

I cannot refrain from admitting that the conception of taurodontism as defined by Keith is not at all clear. Three different things have been thrown into confusion. First, that author speaks of the supra-alveolar position of the teeth which however only concerns the relation between teeth and alveolar process, that is to say, the manner in which the entire tooth is embedded in the jaw; second, he refers to the proportion of size to height, namely of that undivided portion of the tooth which he termed "body" and that represented by its divided portion and third, he points to the roominess of the pulp cavity and its extension toward the root.

From Keith's second publication on this subject it follows that he confined the term "taurodontism" more and more only to the last enumerated phenomenon so that the entire problem has become much more simple. There only remains the question whether a large pulp cavity extending toward the root is an exclusively characteristic feature of the teeth of the Neanderthal group, a condition not observed either in recent man nor in anthropoids.

Before entering into a discussion, however, it is necessary to acquire a better definition of the various portions of the tooth than that used by Keith and other authors. It is common knowledge that the problem in question arose first after the discovery of the Krapina molars. These teeth show the peculiarity that the roots are not divided into three or two branches but instead form in many cases a unique and more or less prismatic stem with the pulp cavity likewise extending undivided through the stem. These features have been the subject of lengthy and exhaustive debates between Gorjanovic-Kramberger (1906, 1907, 1910) and Adloff (1907, 1908, 1910) so that it may be sufficient to refer the reader to the literature listed for further details. It is important, however, that Adloff in contrast to Gorjanovic-Kramberger considers the existence of this peculiarity of the Krapina molars as a specialization which excludes the Krapina man from the ancestry of recent man. Keith later adopted Adloff's viewpoint. Adloff's interpretation also is not quite clear as to whether the specialization assumed by him only concerns the form of the root or includes also the enlargement of the pulp cavity though in one of his publications (1910) it seems to point more toward the first mentioned direction.

As noted above, when describing the roots of the *Sinanthropus* molars the terms "body" or "corpus"—the latter term was used by Davidson Black (1927)—are not correct. Teeth have only two and not three portions, namely the crown and the root, the neck marking the boundary between crown and root. The "body" as is understood by Keith does not represent a portion of the entire tooth but only a part of the root. Generally, the root again composes two portions: an undivided stem and its branches which may number two or three according to the tooth type concerned. Whether the stem is high or low depends only upon the level at which the division takes place. If this division is absent, then the stem continues up to the real end of the root. This is the case in some of the Krapina molars. Thus it is erroneous to speak of fused roots as is commonly done including the present writer. This, of course, is true not only of the Krapina molars but also of all other cases notwithstanding the fact whether we are dealing with the teeth of hominids or anthropoids. "Fused" roots in no case infer that their branches had at one time been completely separated and become "fused" subsequently, but that a division had never existed. However, it is not sufficiently known whether the reason for the supression of division should be looked for in the conditions of the teeth or in those of the alveoli. In any case, the supression itself is not a phenomenon peculiar to one stock of hominids but only the special manner in which it is manifested.

That differences exist in the degree in which the three lower molars are embedded within the mandible, as Keith describes to be characteristic for recent man, depends rather exclusively upon the age of the tooth. The third molar erupting last and occasionally retardedly will always be implanted deeper than the first one. In addition, the upper border of the alveolar process ascends in passing from the first to the third molar as a consequence of the mandible. These conditions may be found not only in recent man (figs. 319, 322, 324) but also in anthropoids (figs. 306, 318, 320, 321) and all monkeys; they are likewise very pronounced in the *Sinanthropus* mandibles (figs. 265 and 307).

Thus only the height of the undivided stem of the root and the extension of the pulp cavity remain which may perhaps represent two features peculiar to certain fossil hominids. As shown in a previous chapter dealing with the roots of the lower molars, it occasionally occurs in *Sinanthropus* that the stem of the root is higher on the lingual than on the buccal side (compare figs. 139, 142). However, this phenomenon is not a consequence of an unequal division of the root but rather of an unequal height of the crown with the enamel reaching further donwnwards on the buccal than on the lingual side. Davidson Black (1927a) in using the method of measurements recommended by Hrdlicka (1922) for the *Sinanthropus* molar No. 34 (fig. 144) found the ratio between the "corpus height" and the crown height (51.5) to be lower than in any other hominid or anthropoid. In the *Sinanthropus* molar illustrated as figure 139 the ratio (78.2) is much higher and ranges between Black's results for chimpanzee and recent man. I am under the impression, however, that the ratio in question is without any value for comparative studies because of its great individual variability and the difficulty to determine the real height of the protoconid in worn cusps. The individual variability renders it impossible to obtain an actually reliable measurement of the height of the crown plus stem of the root. Judging from all my own observations, there are no essential differences in this respect between *Sinanthropus* and recent man (compare fig. 142, *b* with fig. 146, *a-c*) on one side and anthropoids on the other.

In the description of molars reference was already made in regard to the relation between crown and root with respect to their respective longitudinal and transversal diameters. It was shown that in some cases of *Sinanthropus* the crown does not project over the neck like in the case given in figures 142, 172 and 180, while in other (figs. 139, 140, 148) the neck region is distinctly constricted. In the first instance crown and stem of the root seem to form a more distinct structural unit than in the latter case. But even that equality between crown and root may also be found in recent man (fig. 146, *a-c*) and cannot be considered to be peculiar to *Sinanthropus*.

Of all features implied by the conception of "taurodontism" therefore remains nothing more than the position and roominess of the pulp cavity. Keith (1913) stressed the fact that in Neanderthal man the pulp cavity extends deeply into the region of the root, a phenomenon which he apparently considers as an indication of specialization. The position of the cavity, however, is the same in principle as in recent man, for it is not located within the crown area but occupies the neck and stem region. Rebel (1931) in describing the pulp cavity emphasizes this fact. In his figure 2501 there is reproduced a transversal section of a lower molar of recent man to demonstrate the exact position of the pulp cavity. In comparing that figure reproduced here as figure 234 with figure 138 illustrating the same section of a *Sinanthropus* lower molar, it becomes evident that the essential difference is only the largeness of the cavity and not so much its general localization. It is true that the cavity in *Sinanthropus* approaches the lower border of the stem region closer than in recent man. Nevertheless, both figures at the same time reveal that the greater extension of the cavity in the case of *Sinanthropus* is correlated with a characteristic difference in the entire form of the crown. I had earlier in this study called attention to the fact that the crown of the *Sinanthropus* molars is much lower in relation to the length and breadth than is true in recent man. This apparently also holds good for the form of the pulp cavity and affects the position within the tooth. Therefore the special position of the pulp cavity is not an isolated topographical character and can only be understood when considering the tooth as a whole.

As to the roominess of the cavity one of the essential points is its great variability in recent man. This variability depends not only upon the individual age of the respective tooth but also on the racial affinity of the individual himself. It is a long acknowledged fact that the largeness of cavity is greatest in immature teeth which gradually decreases by increasing age. The diminution of the cavity takes place by a new formation of secondary dentine deposited in particular on roof and floor. For further details the reader is referred to the studies of Szabó (1900), Trueb (1909) and Wagner (1927). According to Szabó the decrease in height amounts to 0.6 mm from the age of 6 to that of 17 and the total decrease from the age of 6 to that of 60 with an original height of 3.0 mm may amount to 2.3 mm. This fact must be kept in mind when the teeth of fossil hominids are compared with those of recent man for it shows that only teeth of the same age are directly comparable with each other as already pointed out by Adloff (1911, his fig. 3). It is furthermore easy to demonstrate in almost every denture that the roominess of the pulp cavity decreases passing from the third to the first molar which, of course, corresponds to the differences in age, the third molar always erupting later than the first one. This holds good not only for recent man but also for the fossil hominids including *Sinanthropus* and the apes. Virchow (1920) already illustrated these conditions in apes by skiagrams of mandibles of a juvenile and adult gibbon (his plate VIII, figs. 5 and 6).

The diminution of the pulp cavity of lower molars by increasing age is illustrated by figures 310-312 in which the letter *a* designates the immature stages and letter *b* the adult ones: figure 310 represents chimpanzee; figure 311 *Sinanthropus*, *a* a large type (No. 36) and *b* a small type (No. 38); figure 312 gives molars of juvenile and adult European individuals. In all three cases the pulp cavity is in direct relation to the size of the whole undivided portion of the root larger in the immature teeth than in the adult. Nevertheless there is a difference in the roominess in so far that in the given example of an adult recent man (fig. 312, *b*) the pulp cavity is considerably smaller than in the corresponding case of *Sinanthropus* (fig. 311, *b*) and chimpanzee (fig. 310, *b*). The fact that the cavity is always smaller in the first molar than in the second and third is evident from the skiagrams given in figures 237, 307, 309 and 314-324. In this respect there is no difference between *Sinanthropus*, Neanderthal man, recent man and the anthropoids: figures 307, 309 and 314 represent the *Sinanthropus* mandibles G I, K I and A II; figure 315 the Heidelberg mandible—after Schoetensack—; figure 237 the mandible of La Quina after H. Martin; figure 316 represents the mandible of Palæolithic recent man of Choukoutien; figure 323 the Wadjak mandible; figure 319 a modern Eskimo; figure 322 an Australian native; figure 324 a modern North Chinese; figures 318, 320 and 321 illustrate mandibles of gorilla and orang, respectively.

However even if the variability in roominess as a consequence of the respective age of the tooth is taken into consideration, there is no doubt that the pulp cavity of the *Sinanthropus* molar is considerably larger than that of the corresponding molars of recent man, yet with the reservation as far as the average recent man is concerned. Davidson Black (1927a) showed that in the *Sinanthropus* molar No. 44 the height of the pulp cavity is more than twice that of a recent Chinese and more than three times that of a chimpanzee. In my opinion it is useless to make exact measurements of the size of the respective cavities selected because of their great variability. It is sufficient to ascertain that in all cases of *Sinanthropus* molars of which skiagrams have been prepared from mandibles or isolated teeth the roominess of the pulp cavity was found to be very great in adult and strongly worn teeth also. This does not only hold good for the lower molars (figs. 138, 307, 309, 311, 314) but also for the upper molars (figs. 308 and 313). Furthermore, it is remarkable that the pulp chambers of the distal branch of the root of the lower molars and of the buccal branch in the upper molars also take part in this enlargement. If under the term "taurodontism" only this peculiarity is understood, then there remains no doubt that it exists in *Sinanthropus*.

Davidson Black (1927a) believed that the taurodontism as evident in the *Sinanthropus* molars must be distinguished from the taurodontism within the Neanderthal group considering the latter an exaggerated product of an advanced specialization and resulting from degenerative changes. He thus brings the taurodontism in *Sinanthropus* into closer connection with that of the Heidelberg molars and designated the condition as "moderate taurodontism" considering this form of taurodontism the only primitive hominid character. It is obvious that Davidson Black in making such a discrimination had in mind certain Krapina molars, for in reality there does not exist the slightest difference between the taurodontism in *Sinanthropus* molars and that of the typical Neanderthal group. As most of the features involved are well known and illustrated in the majority of the literature available, I shall confine myself to reproducing here only the skiagram of the Heidelberg molars (fig. 315) and a drawing of the La Quina molars (fig. 237) according to a skiagram of H. Martin (1923). The "exaggerated taurodontism" to which Black refers concerns exclusively a certain number of anomalous Krapina molars with so-called prismatic roots which cannot be taken to be specific for the molars of Neanderthal man as such. I shall refer to this question below.

Davidson Black is fully justified, however, in considering a large pulp cavity a characteristic criterion for primitive hominids. As a matter of fact, it occurs in all *Sinanthropus* molars and not only in molars but also in premolars as is evident from a comparison of the premolars represented in skiagrams of figures 307 and 309 with the corresponding teeth of a recent Chinese (fig. 324). Yet this feature is not confined to *Sinanthropus* but is also characteristic for the entire Neanderthal group. Within this group it occurs in the molars of the Heidelberg (fig. 315), La Quina (fig. 237), Krapina, Le Moustier and Gibraltar (fig. 236) mandibles. The latter facts apparently also induced Gregory (1922) to state that "a moderate degree of taurodontism is a primitive feature for the hominids."

The conception that taurodontism must be considered a specialization as assumed by Keith is based on two suppositions. First, it should not be transmitted to recent man and second, it should never be found in anthropoids. I must say it is rather surprising that such an opinion could be maintained for so long, for both suppositions are erroneous as has been proven already many years ago. As to the first mentioned claim Shaw (1928) proved that large pulp cavities are very common within the native population of South Africa of today. That author differentiates three degrees of taurodontism, namely hypertaurodontism as represented by certain Krapina molars, mesotaurodontism as found in the Neanderthal group and finally hypotaurondontism as present in recent Bantu-Boskop hybrids. Shaw found "taurodont skulls" in the following percentage:

Bantu	with	Boskopoid element	36.3%
Bush	"	Boskopoid element	33.3
Bush	"	Australoid element	41.6

Total number?

and concludes: "Since taurodont races can intermingle with cynodont races of mankind and produce fertile offspring, taurodontism is not a character of zoological species rank." Earlier (1918) Gerrit S. Miller found taurodont molars in ancient Egyptians and modern American Indians. In the mandible of Palæolithic recent man of Choukoutien (fig. 316) the molars exhibit a moderate degree of taurodontism and the same is true for the Wadjak mandible (fig. 323) and the Eskimo molars represented in figure 319. Of course, there is a difference when compared with *Sinanthropus*. This difference concerns the roominess of the pulp cavity and its special form. Furthermore, the enlarged cavity in modern man is distinctly smaller than in fossil man which apparently is a consequence of the great reduction in size of the molars as a whole. Apart from this, however, the pulp cavity is specially shortened in mesiodistal direction. This reduction also must be considered a direct consequence of the considerable diminution of the molars in this direction as shown above. If the diminution commonly is still more advanced in recent man than in those rare cases just described or given in the literature, it must be considered as a special change concomittant with the decrease in size and robustness of the molars in the course of human evolution.

It must be kept in mind, however, that even within the Neanderthal group there are molars which do not differ from those of recent man in regard to the smallness of the pulp cavity. According to Virchow (1920) the pulp cavity of the molars of the adult Ehringsdorf mandible is narrowed in the same way as in recent molars, namely the roof and floor almost touch each other. Figure 238 represents a copy of Virchow's diagram. Considering the fact that the molar in question is that of an old individual Virchow assumes it possible that such a narrowness may occur in molars of fossil hominids in general when they have reached the age. In *Sinanthropus* the conditions are certainly different; for even in badly worn molars in which the greatest part of the crown has been worn off, the pulp cavity is still much larger than in corresponding teeth of recent man.

It is a widely distributed assumption that "taurodontism", that is to say, large pulp cavities, does not occur in anthropoids, hence the conception of specialization in fossil man. Gerrit Miller already in 1918 proved that typical taurodont molars may be found in chimpanzee as well as in orang. In his plate I, fig. 2, he illustrates this fact by a skiagram of orang molars. I can fully confirm Miller's statement. In our relatively small collection of adult orangs there is *one female specimen* (fig. 320) with strongly worn molars but with typical taurodontism, the pulp cavities revealing exactly the same degree of extension as in the *Sinanthropus* molars (compare figs. 307, 309, 314). Another female orang of our collection (fig. 321) displays narrower cavities. The same is true of the female gorilla presented in figure 318. It would be interesting to know the exact conditions in *Australopithecus*. Unfortunately, the skiagrams given by Dart (1934) are too indistinct too permit judgement and besides the molars of this specimen are not fully developed. With reference to *Dryopithecus* Gregory and Hellman (1926) supplied many skiagrams (plates 20-22) but none of them allow a definition of the character of the pulp cavities. Our own collection of fossil orang molars also fails to yield any information in this respect, since the teeth either represent immature types or the roots are broken off or lost exactly in the stem region. But in any case the fact that taurodontism occurs occasionally also in anthropoids (orang and chimpanzee) of today is sufficient to arrive at certain conclusions: Taurodontism as found in fossil hominids (*Sinanthropus*, Neanderthal man) is a characteristic primitive feature and cannot be taken as an indication of specialization. It disappears in the course of human evolution but may also be observed to persist in recent man, in palæolithic as well as modern, in the latter case apparently confined to certain races (Eskimo, Bushman, Amerindians). Its occurrence in recent anthropoids, although restricted to individual cases of chimpanzee and orang, indicates that taurodontism must have been characteristic for the unknown ancestor of anthropoids and hominids and has the tendency to disappear in both these groups, neither group having reached the final stage completely. This fact adequately explains the great variability prevailing in recent man. Thus, it is also impossible and unnecessary to distinguish sharply between different degrees of taurodontism as proposed by certain authors.

There is one exception, however, namely the special case of the Krapina molars. As has been described by Gorjanovic-Kramberger (1906), approximately 50% of the upper and lower molars exhibit roots which are not at all divided or in which the division has taken place very close to the apex of the root. This root is not solid but the pulp cavity extends in its entirety up to its end or the point of bifurcation. In the latter case the cavity is closed by a special lid-like structure. Gorjanovic-Kramberger and Adloff debated on this feature for years. The former author believed that the Krapina man, despite of this peculiarity, is in direct ancestry of recent man, while the latter insisted that the differentiation in question must be considered a typical specialization excluding the entire Krapina population from the ancestry of recent man. Figure 235 represents a copy of Gorjanovic-Kramberger's skiagram (1910) showing the characteristic appearance of such affected roots. The only difference from normal roots is the great extension of the undivided stem toward the apex of the tooth with the division in the usual level having failed to occur in such a case. As in the course of normal ontogenetic development the stem of the root is formed first and the division represents a secondary stage, the special feature in question in reality is nothing else but an anomalous persistence of juvenile conditions. It is of significance in this respect that the anomaly has been found most pronounced and most frequent in third molars.

In *Sinanthropus* or other fossil hominids a similar feature does not exist. Keith (1924) however described the same formation in molars of Malta and St. Brelade which he considers to be Neanderthal types. No case of its occurrence in recent man is reported until now in the literature. Therefore, the roots of the Krapina molars seem to be actually representing a feature peculiar to that hominid type. Even so, there is not the slightest justification for considering the Krapina population in general as a specialized discontinued branch of hominids. For the malformation is found in only about one half of the cases, being absent in, for instance, the mandibles E and F (Gorjanovic-Kramberger, 1910). At best one could assume that individuals affected with such anomalous roots have left no direct descendants within recent mankind. But even for such a restriction real evidence is lacking because is is not known whether the malformation of the Krapina molar roots has been of dominant character or has disappeared in the descendant by breeding with nonaffected individuals. There are a great number of malformations in recent man with the latter alternative. This standpoint is in full conformity with Gregory's (1922) conception of the feature discussed. Eugen Fischer (1913) in summarizing his views on the Krapina problems stated that no phylogenetic conclusions can be drawn from those anomalous formations either in a positive nor in a negative sense.

Taking all these facts into consideration, it seems to me that the time has come to definitely drop the so-called taurodontism, even in its exaggerated form as met with in certain Krapina molars, as an argument against the direct relationship between recent man and not only the Krapina individuals but also the entire Neanderthal group. As proven by *Sinanthropus* the roominess of the pulp cavity is a primitive hominid character which has become lost as a consequence of the reduction of the entire tooth in the course of human evolution.

B. THE DECIDUOUS DENTITION

The deciduous dentition of *Sinanthropus* is of the greatest importance because for the first time such a complete and well preserved collection of deciduous teeth of a fossil hominid has become available. Hitherto, we were only familiar with a certain number of milk teeth of the Neanderthal group, namely with those of the Krapina man and the Gibraltar child. The Krapina teeth, however, represent isolated specimens and apparently are in such poor conditions that Gorjanovic-Kramberger (1906) did not attempt to give more than a very cursory description. Of the Gibraltar child m_1 and m_2 are preserved *in situ* and also only briefly described by Buxton (1928).

The deciduous teeth of *Sinanthropus* are represented by 13 specimens, 12 *in situ* and only 1 isolated, all of which belong to the lower dentition. Most of the specimens are well preserved and, though partly worn, permit an accurate judgement of their characteristic features. As to the individual types, there is only one central and one lateral incisor. The crown of the latter is rather damaged with only an insignificant part of the cutting edge preserved. In addition, there are three canines, one of which is in excellent state of preservation and does not show the slightest trace of attrition. Of the three first molars there are only two available for comparison, the crown of the third one being broken off. The second molars are represented by five specimens, three of which are only slightly worn.

In respect to size, the majority of these teeth are relatively very small, with the exception of two which belong to mandible B III and may represent the large (male) type.

TABLE XXV

Measurements of all available deciduous teeth

156 [illegible] 202 203 243

		i_1 No. 118 ♀	c_1 No. 120 ♀	252 c_1 No. 121 ♀	c_1 No. 122 ♀	m_1 No. 123 ♀	m_1 No. 124 ♂	m_1 No. 125 ♀	m_2 No. 126 ♀	m_2 No. 127 ♂	m_2 No. 128 ♀	m_2 No. 129 ♂	m_2 No. 139' ♀
crown	height	(3.7)	7.0	—	—	—	—	(6.5)	—	—	(6.7)	—	(4.9)
	length	4.3	6.1	6.2	6.2	7.7	—	9.8	10.5	12.2	11.7	11.2	10.9
	breadth	3.6	5.3	5.3	5.2	6.6	—	7.0	9.0	10.1	8.4	9.9	8.9
	length-breadth index	—	—	—	—	85.7	—	71.2	85.8	82.8	71.7	88.2	81.4
root	length	3.1	4.7	—	—	—	8.2	—	—	—	—	—	—
	breadth	3.3	4.1	—	—	—	7.0	—	—	—	—	—	—

1. INCISORS (figs. 186, 299, 303)

The general appearance of the central incisor exhibits the same peculiarity which characterizes all permanent teeth of *Sinanthropus*. Although small, it is a very stout tooth with the upper portion of the root only slightly shorter and narrower than the crown (fig. 186, *a-d*). The latter has a wedge-like form. Viewed from the mesial or distal side the crown is broad and overhangs at its base, thinning out gradually and equally on either side toward the cutting edge. The mesial and the distal sides themselves represent a triangular field with thickened borders continuing towards the edge. The buccal surface is somewhat longer at the edge than at the base and is moderately convex (*o*); the lingual side is slightly deepened so that its base forms a rounded swelling overlapping the neck. The cutting edge is not preserved.

The root is relatively long, very strong and almost circular in cross section. The apical portion is eroded already by the permanent incisor (fig. 303).

The basal swelling of the lingual surface, together with the peculiar triangular field of the mesial and distal sides, resemble the conditions described above as characteristic for the permanent canines. In the case of the incisor this structure must be considered as a derivative or remnant of a primary cingulum, while the lingual tubercle is only faintly indicated.

In recent man (fig. 187) the crown is much more slender and narrower toward the edge and the entire pattern of the surfaces has become obscure so that their real nature can only be judged when compared with the original pattern of *Sinanthropus*. The root is remarkably reduced in robustness.

The central incisors of anthropoids are approximately the same when compared with each other and differ from those of *Sinanthropus* only in the more pronounced development of the basal swelling of the lingual surface and its stronger projection.

In all three anthropoids the surface also shows a slight median elevation. The most striking peculiarity, however, of anthropoids is their differences in size, those of orang and chimpanzee being so much larger than those of gorilla that even the incisors of a male gorilla are inferior to those of a female chimpanzee. *Sinanthropus* closely resembles the gorilla in this respect. I shall return to this question below.

The description of the Krapina incisor given by Gorjanovic-Kramberger unfortunately is so vague as to make it impossible to derive therefrom the feature specific for the Neanderthal type.

The crown of the lateral incisor (fig. 299) of *Sinanthropus* is too damaged to warrant a description.

2. CANINE (figs. 188, 190, 191, 193, *b*; 299, 303).

The general appearance of the *Sinanthropus* canine displays that disproportion between crown and root which is so characteristic for the central incisor, in a still more pronounced way (figs. 190, *b*; 193, *b*). The root is very long and strong and the crown appears only as a small hood placed upon it. The crown itself is long in relation to its height (fig. 188, *b*, *l*) and equally pointed.

The buccal surface is bordered by a basal arch-like swelling which ascends toward each side, to a higher level on the mesial than on the distal side. At each termination of this swelling the cutting edge begins, culminating at the tip which is slightly shifted mesialwards. The surface itself is strongly convex with an additional distinct and broad elevation in the median region. The basal swelling in the case illustrated in figure 190 is very pronounced and appears as a special rim folded outward on the distal border.

The lingual surface (figs. 188, *l*, *o*; 190, *l* and 191) is slightly concave and bordered on all three sides by a thickened rim. This rim as evident in figure 190 takes the character of a distinct fold, especially in its basal parts.

Toward the tip a small elevation is present which ends in a knob-like thickening at the tip. The mesial side (figs. 188, *m* and 190, *m*) offers a similar aspect as in the central incisor, namely a triangular field is formed by the meeting of the basal swellings of the buccal and lingual sides the apex of which continues directly into the cutting edge. The distal side, slightly damaged in the specimen presented in figures 188, shows a special feature in so far that the basal structure projects stronger lingualwards here (*o*). This peculiarity makes the tooth appear asymmetrical when viewed from above (figs. 188, *o* and 190, *o*). In figure 190 there is even a double fold at this point. It is surprising how close the entire appearance of the crown of this lower deciduous canine conforms to that of the permanent upper canine of *Sinanthropus* (compare figs. 38 and 39), the former representing only a miniature pattern of the latter. This holds good not only for the basal structure with its mesial and distal differentiations but also for the configuration of the upper parts. For the basal structure of the deciduous canine must be considered as a typical cingulum which ascends, as shown above, always to a higher level on the mesial than on the distal side.

The root of the *Sinanthropus* canine (fig. 193, *b*) is long, broad and almost entirely circular in cross section. The circuit remains approximately the same up to the end of the root (the apex itself is eroded). The crown overlaps the root considerably, especially on the mesial and distal sides.

In comparing the *Sinanthropus* deciduous canine with that of recent man (figs. 189, 193, *a*) the differences as far as their general appearance is concerned have the same character as those observed in the permanent dentition. The crown of the canine of recent man is higher but narrower and the whole pattern is obscured and its details can only be defined on the basis of the *Sinanthropus* pattern. Although the recent canine is relatively higher than that of *Sinanthropus* the latter is much more pointed, the angle formed by the mesial and distal section of the cutting edge amounting to approximately 87° against about 94° in recent man. Differences likewise exist in regard to the roots. That of the recent canine is slender in relation to the size of the crown and tapers off and there is only a slight overlapping of the crown.

The deciduous canine of recent anthropoids is much higher and much more pointed than that of *Sinanthropus*. However, it conforms to the latter in regard to the development and the differentiations of the cingulum, at least as far as the orang is concerned. The resemblance of the *Sinanthropus* deciduous canine to that of the orang also concerns the special shape of the crown. The latter is more compressed in buccolingual direction in orang, while in chimpanzee and gorilla the crowns are rather pyramid-like with one edge descending more in distolingual direction. Thus when these canines are viewed from above, the distolingual portion appears to be more accentuated than the other. The existing differences become much less significant when the deciduous canine of a fossil orang is taken for comparison (fig. 192). This canine is much stronger in crown and root than that of *Sinanthropus*. However, not only the proportion of crown to root but also the proportion of the crown itself are strikingly similar to *Sinanthropus*. Such conformity is also true for the cingulum and the configuration of the lingual surface, with the exception that here two median ridges emerging from the tip are developed. The double fold of the distal border of the lingual surface in *Sinanthropus* given in figure 190, *l*, seems to correspond to the marginal and the distal ridges of the two median ridges in fossil orang, while the asymmetry in favour of the distolingual edge in *Sinanthropus* (fig. 188, *o*) must be considered to be the same formation just described of chimpanzee and gorilla. It can therefore be stated that the canine of *Sinanthropus* resembles that of this orang even closer than that of recent man.

As to the deciduous canine of the Neanderthal group the brief description given by Gorjanovic-Kramberger (1906) shows that the canine of the Krapina man resembles in the triangular shape of its crown and the special formation of its buccal surface with its elevated middle part the *Sinanthropus* tooth structure. This is also true of the basal part of the lingual surface.

3. MOLARS

In the general discussion on the position of hominids in relation to anthropoids the deciduous molars were given much more attention than the incisors or even the canines. In his often cited book Adloff (1908) claims that the deciduous molars of man, especially the first one, should be primitive and those of anthropoids specialized *with the result that the entire first dentition of anthropoids* must be considered to be as fundamentally different from that of hominids as should be true for the permanent dentition.

a. THE FIRST MOLAR (figs. 194, 199, 299, 303)

The best preserved first molar is somewhat worn. The wear is evident by the smoothness of the talonid basin and in particular by the leveling of the protoconid to such an extent as to expose the dentine (figs. 194, *m*, *o*). The crown is long and narrow (index: 71.5) and relatively low, despite the height of the protoconid itself the supposed original height of which is marked by dotted line in figure 194, *b*; this restoration was made on the basis of the extension of the worn off part.

The buccal surface is bordered at its base by a very pronounced cingulum which causes the mesial moiety to overlap and descend considerably (fig. 194, *m*) that gives the tooth when viewed from the mesial side a rather peculiar aspect. This feature corresponds to the so-called "tuberculum molare" in recent man (fig. 198, *b*, *m*). The buccal surface itself recedes considerably and is divided by two deep furrows in three areas of unequal size. The middle area is the largest and corresponds to the protoconid. The position and direction of its attrition facet indicates that this cusp was pointed with the tip closer situated to its mesial border (fig. 194, *b*, *l*). The distal area is represented by the much lower hypoconid. The most interesting portion of the buccal surface, however, is the mesial one. It appears to consist of the ascending portion of the cingulum reaching the chewing surface itself and continues into the mesial edge which borders the mesial surface (compare 194, *o*). Yet, the occlusal and especially the mesial (m) views reveal that in reality there is no continuous line at all but the point in which the ascending portion of the cingulum meets with the horizontal is marked by a distinct and faintly pointed elevation (fig. 194, *b*, *m*, *o*) representing nothing else but the paraconid.

The lingual surface (fig. 194, *l*) of the crown exhibits that the crown here is much lower than on the opposite side. Furthermore, there is no special subdivision with the exception that the metaconid rises above the chewing surface in the form of a well pointed cusp. The characteristic feature of the mesial surface (m) has already been mentioned. In addition, it reveals the real position of the two or better three trigonid cusps.

The distal surface (d) fails to show any peculiarity but the distal view displays very distinctly that the trigonid portion of the molar is much higher than the talonid one, a condition also observable by buccal and lingual views (*b*, *l*).

The occlusal view (o) completes the picture of the molar pattern furnished by the other aspects. The most striking one is the presence of a completely regular trigonid with the three cusps and both mesial and distal crests. The protoconid occupies the apex of this triangle, while the basal angles are formed by the metaconid and the paraconid. The only divergence is the smallness of the paraconid and its being shifted closer to the buccal side and to the protoconid. The distal trigonid crest emerges from the distal spur of the protoconid and courses in a wide arch directly to the tip of the metaconid. The mesial trigonid crest emerges from the mesial spur of the protoconid and terminates in a very short distance in the paraconid. The paraconid continues lingual- and distalwards along the thickened mesial edge which is separated from the metaconid by a distinct indentation (fig. 194, *l*, *o*). The trigonid basin is represented by a V-shaped depression the apex of which corresponds to the just described indentation. The walls of the basin are formed by the respective slopes of the protoconid and metaconid and the mesial edge connecting the paraconid with the metaconid. The talonid portion of the molar is formed on the buccal side by the hypoconid which represents an extensive ridge without any distinct tip (caused by attrition?), and on the lingual side by the distal spur of the metaconid; the hypoconid ridge and this spur continue from both sides into the distal edge. There is no indication of additional cusps or elevations. Whether this peculiarity represents a consequence of attrition or an original character I do not venture to state. The talonid is an oval basin surrounded by the formations just described. It is separated from the trigonid by the distal trigonid crest and the slope of the metaconid. That the entire trigonid portion rises to a higher level than the talonid has already been mentioned. The trigonid basin is shorter and narrower than the talonid basin but the trigonid as a whole, which embraces the entire area of protoconid and metaconid, is as large and long as the heel-like talonid. In spite of the relative smoothness of the trigonid and talonid—the latter probably due to attrition —there are indications that wrinkles have existed. The protoconid slope bordering the trigonid basin and the metaconid slope bordering the talonid basin show few accessory ridges.

The root consists of a low stem and two widely diverging and curved branches with a broader mesial and a narrow distal one (fig. 303). The former is obliquely orientated with its buccal side turned mesialwards, while the latter exhibits a plain transversal direction (fig. 341).

The other first molar of *Sinanthropus* of which the crown is preserved (fig. 199) is so worn that details of its pattern may only be defined as far as the mesial part of the trigonid is concerned. In this case there is also a well developed cingulum with a distinct tuberculum molare (fig. 199). The trigonid basin with the bordering structures. namely the basis of the paraconid, the protoconid and the metaconid and the ends of the mesial and distal crests are still recognizable. The extent of this area corresponds to the inferior size of the entire tooth which is very small.

The first molar of recent man (figs. 198, 206) differs in a very characteristic manner from that of *Sinanthropus*. The difference in size is, curiously, much lower than in the permanent teeth, and still more striking is the difference in shape. When the buccal and mesial surfaces are compared (figs. 194, *b*, *m* and 198, *b*, *m*), then it may be observed that the tuberculum molare is developed in recent man also, but since every indication of a cingulum is lacking this tubercle is much less distinct than in *Sinanthropus*. The greatest difference, however, concerns the mesial area of the crown. In recent man the mesial side of the buccal surface appears to be shortened and cut off vertically. The ascending portion of the cingulum and the paraconid are lacking. This will become particularly evident when comparing the mesial surfaces (m). The protoconid of recent man is much lower and less pointed and the same is true for the metaconid (l). The talonid is only slightly lower than the trigonid. As is revealed by the occlusal views (o) the areas of the trigonid and talonid are still distinguishable but all contours are completely smooth and obscure. Bennejeant's (1936) claims that the paraconid forms a regular component of the pattern apparently contradict the facts. The general contours of the trigonid, it is true, are preserved but not this cusp. The molar gives the impression as if all the projecting parts had been ground off and subsequently polished. The root has the same character as in *Sinanthropus*, except that it is much weaker and more slender.

In describing the permanent molars attention was already called to the fact repeatedly that there were great differences within the various recent races of mankind in regard to the special appearance of the tooth pattern. The same is true of the deciduous molars. Figure 206 illustrates the first molar of a North Chinese child. Apart from the fact that this tooth is much shorter but broader than that of *Sinanthropus* (length-breadth index: 91.2), the buccal surface shows an indication of a cingulum, at least its ascending portion, and a special relief. In addition, the chewing surface is very complicated, not only because of the existence of relatively numerous wrinkles but also because of a segmentation of the entire border of the talonid with the result that four distinct tubercles (hypoconid, entoconid and two between them) are recognizable. In the trigonid portion the paraconid is indicated and likewise the sharply bordered basin; the mesial crest is also discernable. In most cases the trigonid is longer than the talonid.

The first molar of the anthropoids (figs. 195, 197, 200, 210) resembles in its long oval shape (length-breadth indices: orang 64.0, gorilla 67.2) very closely the *Sinanthropus* molar. The only major difference concerns the configuration of the trigonid portion. The entire trigonid area seems to be transformed into a uniform elevation with the tip of the protoconid representing the highest point. From here a crest courses down and mesialwards to the tapering mesial end of the tooth; it terminates again in a fine point at which the cingulum ascending on the buccal side meets the border of the chewing surface (figs. 195, 197, 200, 210). This point may correspond to the paraconid. The metaconid is merged with the protoconid, only its tip is left and appears as a second tip of the protoconid situated more or less lingual- and distalwards. The trigonid basin has been lost completely. Because of this transformation the trigonid area has adopted the character of a sectorial pattern. The three anthropoids differ in regard to this pattern chiefly in the degree in which the metaconid retains its independence. It may be closely attached to the protoconid or more removed from it. In the specimens at my disposal the distance is shortest in chimpanzee and longest in orang, however great individual variations may be. The talonid portion is considerably lower than the trigonid (fig. 197) and rather resembles a slope of the united proto- and metaconids than an independent appendix of the trigonid. In orang as well as in chimpanzee the chewing surface is covered by wrinkles. They show the same character as in the permanent molars, with the exception that they are finer in structure.

As to the root it is characteristic for all three anthropoids that the anterior branch is obliquely orientated like in *Sinanthropus*.

The description of the anthropoid molar given above is derived from the conception that the conditions peculiar to *Sinanthropus* must be considered as the primary ones and those of the great apes as secondary specializations and not the reverse. This statement is based upon four decisive facts, namely first the individual and group variations within the anthropoids, second the special appearance of the first deciduous molar of *Australopithecus* (see below), third the similarity of the specialization between the first deciduous molar and the first premolar in anthropoids, and fourth the conformity in principle of the second deciduous molar in *Sinanthropus* and anthropoids (see below). The individual and group variations show that no stabilization of the pattern has taken place. However, occasionally the three trigonid cusps in their characteristic mutual position and traces of the respective crests may still be observed.

Unfortunately, no first deciduous molar of *Dryopithecus* or *Sivapithecus* has become available. One milk molar of *Dryopithecus* germanicus has been defined by Gregory and Hellman (1926) to represent a second (see below). The appearance of the first deciduous molars of *Australopithecus* (fig. 201) is of greater importance. These teeth apart from their more square form (length-breadth index according to W. Abel (1931) : 82.7 and 86.2, respectively) and as far as the trigonid is concerned are directly identical with the first deciduous molar of *Sinanthropus* (compare figs. 201 and 194, *a*). The trigonid composed of the strongly worn protoconid, the less worn metaconid, the distal crest connecting both cusps and the reduced paraconid, is easily recognizable despite the attrition. The presence of the latter cusp which marks the end of the ascending portion of the cingulum cannot be doubted as a comparison of the buccal views of the *Australopithecus* (fig. 196) and the *Sinanthropus* (fig. 194, *b*) molars reveals. Like in *Sinanthropus* the paraconid is shifted closer to the buccal side and to the protoconid. The trigonid basin is represented by exactly the same V-shaped pit. The talonid, it is true, seems to be different. First of all it is much shorter and broader (fig. 201) and it is possible that the hypoconid and the entoconid were better developed than in *Sinanthropus*. Whether some significance has to be attached to this peculiar form of the *Australopithecus* tooth is questionable because of the extraordinary variability of the respective outlines in *Sinanthropus*, anthropoids and recent man. The length-breadth index of the *Sinanthropus* molar of figure 194 is 71.5 and that of figure 199 85.7 (*Australopithecus* 82.7 and 86.2 respectively). For the chimpanzee W. Abel (1931) found an index variability ranging from 56.2 to 98.1 on the basis of Remane's measurements. The respective indices for recent man given by W. Abel reveal a variability ranging from 71.2 (Bushman) to 91.4 (Maori). Since *Australopithecus* has to be classified as an anthropoid (see below) there is no doubt that the almost complete preservation of the trigonid in *Sinanthropus* and *Australopithecus* must be taken as a primitive character and its loss in recent anthropoids as secondary differentiation.

The first milk molar of the Neanderthal group is preserved in the Krapina findings and in the mandible of the Gibraltar child. As to the former Gorjanovic-Kramberger (1906) emphasized the fact that the tooth is narrow in the trigonid region, although the crown as a whole is broader than in recent man. He gives the length-breadth index as being 80.2. The tuberculum molare is only faintly developed. The molar of the Gibraltar child (figs. 205 and 209) is, according to Buxton (1928), by no means outside the range of variation in size or pattern of that of recent man. However, as is evident in figure 205, the tooth distinctly tapers off toward the mesial end. Unfortunately, the high degree of attrition does not permit a certain judgement; it seems, however, that the distal trigonid crest connecting the protoconid with the metaconid is still preserved, while the mesial part of the trigonid and the trigonid basin are reduced to a small fissure and the mesial edge bordering the latter. The trigonid is much higher than the talonid (fig. 209). The presence of a cingulum is indicated by a slight swelling at the base of the buccal surface and a fine groove at the boundary between the protoconid and hypoconid areas (fig. 209). A distinct tuberculum molare is missing. The length-breadth index amounts to 93.7 according to Buxton's measurements. The talonid is relatively long and formed by the hypoconid and entoconid and by at least one more tubercle, probably the mesoconid.

As much as could be judged from the scanty material of Neanderthal molars, this type links *Sinanthropus* with recent man. However, the paraconid has already been lost and the entire trigonid region transformed to a great extent into that feature which characterizes recent man.

The tuberculum molare of the first deciduous molar has played a great role in the debate between Remane (1931) and Adloff (1931). In the first permanent premolar of anthropoids, as shown above, the basal part of the crown, together with the buccal side of the mesial branch of the root projects in mesiobuccal direction, a phenomenon associated with and apparently partly dependent upon the sectorial character of the tooth. The sectorial character of the premolar is combined with a large and overlapping upper canine. Thus the same feature in the first deciduous molar may likewise indicate the occurrence of a big and overlapping upper deciduous canine. The crown of the first lower deciduous molar in *Sinanthropus*, it is true, does not show a sectorial pattern but the existence of the tuberculum molare and the position of the mesial branch of the root is the same as in anthropoids with a sectorial structure of the first premolar (compare figs. 194, *m* and 341 with 88). In addition, there is a distinct diastema between canine and the first deciduous molar in *Sinanthropus* (fig. 299, *a*, *b*, *c*, see below). All these features indicate that in *Sinanthropus* or at least in one of the preceding stages of evolution a large upper deciduous canine may have existed. Unfortunately, no such tooth of *Sinanthropus* has as yet been recovered and thus leaves this question open for the present.

Another point which deserves note is the conformity of the sectorial character of the first deciduous molar *and the first permanent premolar in anthropoids and the pure non-sectorial character in the same teeth of Sinanthropus.* Some authors tend to interpret Leche's (1915) proof, namely that the deciduous dentition of mammals has in many cases retained more primitive peculiarities than the permanent dentition, in the sense of Haeckel's law, which means that ontogeny is a recapitulation of phylogeny. Such an interpretation is not quite correct. For there must have been in every stage of phylogenetic evolution of the mammals a deciduous as well as a permanent dentition with the latter at all times replacing the former, thus making it practically impossible for the permanent dentition ever to have functioned in place of the deciduous dentition as apparently implied by that interpretation of Leche's viewpoint. It may occur that a deciduous tooth becomes a permanent one but the reverse is impossible. Each dentition is only a part of the masticatory apparatus and strictly adapted to the special conditions of the latter. At no time during the process of evolution can juvenile jaws which are adapted to accommodate the deciduous dentition also have served to do so for the permanent dentition. There does not exist a genuine homology between the individual types of deciduous and permanent dentition, but only an equivalence. Each dentition follows its own law. Thus, all that we can undertake is to compare the corresponding dentitions with each other, namely the deciduous or the permanent dentition of one stage with the deciduous or permanent of the preceding stage. Primitive structures will be manifest in both dentitions independently. At best it may be that these are retained with more persistence in the deciduous dentition than in the permanent one. Therefore, the fact that deciduous teeth of a given stage of phylogenetic evolution fail to reveal more of a supposed feature than the permanent teeth of the same stage does not at all prove that such a feature had really never existed in an earlier stage.

In the case discussed here the deciduous dentition of *Sinanthropus* shows exactly the same conditions as those applying to the permanent one, namely the first deciduous molar and the first premolar are of a non-sectorial type, although certain other features (tuberculum molare and position of the root) are characteristic for a sectorial type. As the deciduous molar as well as the premolar, in contrast to anthropoids, do not show a sectorial character and the canines conform to this feature, both dentitions reveal the same fact, namely that *Sinanthropus* and the hominids represent a primitive stage of evolution, while the anthropoids have already become differentiated in a special direction. *Australopithecus* is undoubtedly closer to the hominids in this respect than to the anthropoids.

Second molar (figs. 199, 202-204, 211, 299, 303, 343, 344)

The teeth best preserved are reproduced in figures 202 and 343. These molars supplement each other in so far as some of the special features are more distinct in one or the other. In its general appearance the second molar is molarized exactly as much as the first one. With reference to the form there is no essential difference: the molar is oval with a longer longitudinal axis. However, as is true of the first mo'ar, there is a great variability with the length-breadth index ranging from 71.7 to 88.2. The main difference between these molars is that the second is considerably larger than the first one (see below).

The buccal surface is characterized by its strong retrocession lingually (figs. 343, *m*, *d*, *o* and 202, *m*, *o*). This peculiarity causes a strong projection of the basal part of the crown which however is not as distinctly delimited as in the first molar. Furthermore, there is no tuberculum molare nor an overlapping of the enamel. On the other hand there are two indentations (fig. 343, *b* and 202, *b*) cut in rather deeply. In the special case of figure 343 (*b*, *o*) these indentations widen toward the upper border, thus exposing a triangular area. In the case of figure 202 (*b*, *o*) the indentation is narrower and shows more the character of a simple cleft. The indentations separate the protoconid from the hypoconid and the hypoconid from the mesoconid, respectively. There is no doubt that the features in question are the same as those which occasionally are observed to be very pronounced in gorilla (fig. 210). They apparently represent analogies to the stylar cusps with the projecting basal part which forms the lower border of the indentations representing the cingulum. The lingual surface is strongly convex and exhibits only one indentation separating the metaconid from the entoconid (figs. 202, *l* and 343). The mesial and distal surfaces are slightly convex and protruding but do not display any peculiarity worth special note. The trigonid portion of the molar is higher than the talonid. In the case of figure 343 the protoconid is strongly worn (*o*), so that the real conditions may be recognized to better advantage if the molar is viewed from the lingual surface (*l*) with the height of the metaconid exceeding the entoconid considerably.

The most astonishing feature is presented by the chewing surface (fig. 343, *o*). The trigonid here is retained in its entirety, and consists of the very distinct and well separated protoconid on the lingual side and on the opposite side of the paraconid and metaconid. The former cusp is represented only by a minute elevation (pd) on the outermost mesial end of the lingual edge which culminates in the tip of the metaconid (md). It may assumed that the paraconid had been more pronounced than is evident in the molar now and that a part of it was probably lost by contact abrasion (*m*). But its special character is indicated by a fine indentation which separates it from the metaconid (*o*, *l*) and in addition by a fold which descends from the metaconid ridge and terminates at the foot of the protoconid within the trigonid basin. The protoconid is connected with the paraconid on one side by a fine edge representing the mesial border of the chewing surface and considerably thinned by the mesial contact facet (*m*), and on the other with the metaconid by a very distinct and high special crest. The first mentioned edge emerges from the end of the mesial ridge descending from the tip of the protoconid (partly absent due to attrition) and meets the paraconid also on its mesial side; it represents the mesial trigonid crest. The high crest emerges from the buccal edge exactly at the indentation between the end of the distal ridge descending from the tip of the protoconid and that of the corresponding ridge of the hypoconid; it meets the metaconid just at its tip and represents the distal trigonid crest. Both these crests border the trigonid basin composed of a deep pit the walls of which are formed by the crests in question and the slope of the protoconid on the buccal side and the slope of the paraconid and one half of the slope of the metaconid on the lingual one. The distal crest separates the trigonid from the talonid.

The talonid portion of the crown is much larger than the trigonid in longitudinal direction as well as in transversal. It represents in the case of figure 343 a smooth regular basin which is bordered by sharp edges on all sides. However, this peculiar feature apparently is merely a consequence of attrition. For in the case of figure 202 *b* the aspect is very different. In spite of the wear there may be observed in addition to the hypoconid and entoconid two cusps (*d*), one on the buccal side (mesoconid) and one on the lingual (sixth tubercle). Each of these is equipped with a slope of its own the worn facets of which constitute a characteristic feature of the talonid basin (fig. 202, *o*). In figure 343 the basin exhibits fine furrows indicating the boundaries of the cusps and also the presence of several wrinkles. As to the size, the hypoconid in both cases is the largest of the talonid cusps. The arrangement of all cusps—trigonid and talonid—corresponds, so to say, to the "Dryopithecus pattern" with the metaconid representing the largest and in particular the longest cusp. The line separating the trigonid from the talonid courses approximately in transversal direction.

The molar illustrated in figure 202 gives a more detailed outline of the configuration of the trigonid portion in *Sinanthropus*. A distinct paraconid, it is true, is absent but there is a clear distal trigonid crest which descends from the tip of the metaconid and meets the spur of the protoconid at the same point like the one described in the case of figure 343. The crest differs from the latter by three peculiarities, namely it is lower, interrupted by a longitudinal fissure and its lingual portion is subdivided by some distinct wrinkles. The existence of wrinkles characterizes the entire trigonid basin. The basin is larger than in the first described case and yields a more complicated aspect on account of the wrinkles, but in principle it represents a typical trigonid basin despite the absence of the paraconid. The arcade of the mesial edge linking protoconid and metaconid forms the mesial trigonid crest here.

The difference between these two molars in the configuration of the trigonid portion is of considerable importance. For it demonstrates the existence of a great variability also in the deciduous dentition of *Sinanthropus*. This variability reveals exactly the same peculiarity which has been ascertained to be typical of the first and second premolars of *Sinanthropus*, namely as such forming transitions between a primitive stage of evolution (fig. 343) and a more advanced one leading to recent man (fig. 203).

The other preserved crowns of the second *Sinanthropus* molar (figs. 303 and 304) are too worn to shed any further light on the features under discussion.

The root of the molar of figure 343 is broken off. The only detail to be recognized is a distinct constriction of the neck region. In the case given in fig. 202 the constriction is much less distinct (fig. 211, *b*) as is evident from the skiagram (fig. 303). Here the stem of the root is very large and the two branches are low, large and stout. In contrast to the first molar both branches here are orientated in transversal direction. The skiagrams likewise show that the pulp cavity is very extensive and resembles the conditions of the permanent molars.

The second molar of *Sinanthropus* may be compared with that of anthropoids to the best advantage by beginning with Gregory's (1922) statement on the only deciduous molar known hitherto of an extinct anthropoid, namely that of the molar of *Dryopithecus germanicus*. According to Gregory, this molar is more primitive than that of a recent chimpanzee in that it retained a characteristic primitive pattern: the trigonid being smaller and higher than the talonid, the hypoconid less protuberant bucally. In Gregory's figure 287 (p. 380) which is reproduced here as figure 344 there are placed side by side the second deciduous molars of *Dryopithecus* (*c*), chimpanzee (*d*) and recent Amerindian (*e*) with the addition of a permanent molar of an Eocene Tarsioid—Omomys—(*a*) as an example of a very primitive primate molar. The *Sinanthropus* deciduous molar (fig. 343) which has been described above was added by the present author. It is most evident from the illustration that the *Sinanthropus* molar is at least as primitive as that of the stronger worn *Dryopithecus* and certainly much more primitive than that of chimpanzee. The trigonid in relation to the talonid is shorter in *Sinanthropus* than in *Dryopithecus*. The paraconid is more distinct if at all present in the latter and the differentiations of the stylar cusps likewise are better developed in *Sinanthropus*. Furthermore, it is worthy of note that there are distinct traces of wrinkles in the talonid basin of *Dryopithecus* like those described above as characteristic for *Sinanthropus*. The general resemblance between the *Sinanthropus* molars (*b*) and that of the Eocene Tarsioid (*a*) is remarkable. Besides the difference in size, there is one concerning the form of the trigonid in that the original triangle in Omomys has transformed into a more quadrangular form in *Sinanthropus*, apparently in consequence of the reduction of the paraconid and its close approach to the metaconid. In the Tarsioid the protoconid together with the metaconid is the highest cusp. Such was obviously also the case in *Sinanthropus*, since the extension of the abrasion of the protoconid suggests that its actual height was at least as much as has been supplemented in the drawing by dotted lines in buccal view of the tooth (*b*).

The fact that the cingulum and traces of stylar cusps may occasionally be rather well pronounced in gorilla (fig. 210) has already been mentioned above. With reference to the trigonid, it may be well developed in chimpanzee as is evident in figure 212, *a*, *b* but the paraconid is lacking. The molar of gorilla is of special interest in this respect. As Adloff (1906) described, the paraconid has been retained here, a statement which later was confirmed by Remane (1921). In the two cases of unworn deciduous molars of gorilla at my disposal (fig. 208) a distinct paraconid is not recognizable. On the mesial edge of the trigonid portion there is a thickening connected with a ridge which emerges from the tip of the protoconid. Evidently this is the same ridge which Adloff considered to be the mesial trigonid crest. The distal crest linking protoconid and metaconid and the presence of which was likewise asserted by Adloff is clearly observed in figure 208. Remane (1921) in identifying the two trigonid ridges of the permanent lower molars of gorilla with those of the deciduous molar described above accepted Adloff's conception. Earlier herein this question was discussed in detail in connection with the permanent molars, thus I shall confine myself now to the deciduous molars. Firstly, I fail to agree with the identification of the mesial ridge in the gorilla deciduous molar with the mesial trigonid crest. That ridge of the deciduous molar emerges from the tip of the protoconid as the middle one of three ridges, the first one leading directly mesialward to the mesial edge and the third one to the tip of the metaconid. The latter in reality corresponds exactly to the distal trigonid crest as is evident from a comparison with the *Sinanthropus* molar (fig. 343). The middle ridge can never pass as the mesial crest because the latter in no instance emerges from the tip of the protoconid itself but always from the end of its mesial spur. Such a condition can only be carried out by the first ridge, that is to say, the real mesial trigonid crest in gorilla is, like in other anthropoids and *Sinanthropus*, represented by the arcade of the mesial edge itself. The middle ridge of gorilla has no analogue and must be considered to be a special structure confined to this ape.

Remane (1921) in attempting to identify the ridges of the trigonid in the permanent molars of gorilla (see above) refers to the ridges in the second deciduous molars and considers the middle ridge of the latter (fig. 157) as identical with the middle ridge of the deciduous molar and in this way both these ridges as representatives of the mesial trigonid crest. However, the middle ridge of the permanent molar emerges from the tip of the protocone and leads directly to the tip of the metaconid, hence it cannot represent the mesial crest as outlined above. I have the impression that in gorilla molars, deciduous as well as permanent, there is a tendency to duplicate the distal trigonid crest linking protoconid and metaconid: in the deciduous molars the secondary crest is in mesial position to the original crest and in the permanent molars in the distal one. At any rate, in this respect gorilla occupies a special place among the anthropoids and can thus not be taken as prototpye.

The talonid of the second deciduous molar shows some interesting variations within the group of the anthropoids with regard to the number, size and position of the cusps. Remane (1921) reports that in gorilla the mesoconid is usually the smallest cusp and the entoconid the largest. According to the same author the mesoconid can be completely absent in chimpanzee, while on the other hand a sixth accessory cusp situated between mesoconid and entoconid may be found to occur. Even another additional accessory cusp has occasionally been observed. In the gorilla molar illustrated in figure 208 the mesoconid with its position exactly in the longitudinal axis is well developed. the same is true in chimpanzee (fig. 212, *b*). The occurrence of additional cusps observed in chimpanzee is remarkable on account of the same phenomenon occurring in *Sinanthropus* (fig. 202, *o*) Wrinkles are very pronounced in orang, while in chimpanzee and gorilla they are less distinct; in abundance, arrangement and appearance they exhibit the same character as in the permanent molars of the respective genera.

The second molar of *Australopithecus* (fig. 201) unfortunately is too worn in the trigonid portion to permit a completely equivalent comparison. Nevertheless, some details may be recognized. The entire area resembles closely that of the first molar: a distinct paraconid was perhaps not developed, but the distal trigonid crest and the trigonid basin are very clear and show the same appearance as in the first molar. The talonid is much larger than the trigonid; it is formed by four very distinct cusps: the hypoconid which is the largest one, the entoconid and two relatively large distal cusps, a buccal and a lingual one, the former representing the mesoconid and the latter the "sixth tubercle." In spite of the attrition wrinkles are still recognizable. This *Australopithecus* tooth is surprisingly similar to *Sinanthropus* of figure 202 and demonstrates once more the close relationship between this anthropoid and the hominid type. W. Abel (1931) laid special stress upon the more circular form of the *Australopithecus* molar by claiming that this feature should represent a specialization and thereby place *Australopithecus* outside of the hominid order. I hesitate to attribute a decisive taxonomic value to this peculiarity. Abel gives the length-breadth index of the molar in question as being 90.1 and at the same time quoted Remane (1921) according to whom the maximum index for gorilla is 89.6. In the small chimpanzee material at my disposal there is a variability of this index ranging from 73.5 to 87.8 (fig. 212, *a*, *b*).

In comparing the *Sinanthropus* molar with that of recent man (figs. 206, 207), the first difference to be noted is again as in the first molar the difference in proportion of the crown. In *Sinanthropus* (figs. 202 and 343, *b*, *l*) the crown is long and relatively low, while in recent man it is short and relatively high (fig. 207, *b*, *l*). There is no indication of a cingulum or its differentiations. The trigonid is not higher than the talonid, its special feature having been lost completely. There no longer is any direct connection between the protoconid and metaconid. The talonid is formed by the three main cusps, the "*Dryopithecus* pattern" being still retained. The occurrence of a sixth tubercle is not recorded in the literature. Like the crown the stem of the root is considerably reduced in length (compare fig. 211, *a* with *b*) and its branches, especially the mesial one, are weak and curved.

As in the first molar there is here also a great individual and racial variation in the appearance of this tooth. The second molar of a North Chinese child (fig. 206) demonstrates how great the differences may be. In this case there exists a well developed pattern on the buccal surface even with a clear indication of stylar cusps. The trigonid basin is represented by a deep pit but the distal crest has been absorbed into indistinct wrinkles. The talonid is covered by wrinkles and between the hypoconid and the cusp situated at the distal end of the longitudinal axis is one additional and very distinct cusp. I consider this buccal cusp as being the mesoconid because it is separated from the hypoconid by a deep indentation. The cusp on the end may therefore represent the "sixth tubercle" which would be rather large in this case. This occurrence again shows how very urgent and promising a thorough investigation of the tooth pattern of the various races of present mankind is.

Of the second molar of the Neanderthal group very little is known. Gorjanovic-Kramberger (1906) merely remarked that in Krapina man the molar is larger and considerably broader in the level of the hypoconid than in recent man. According to that author the length-breadth index is 88.6-89.0. In the Gibraltar child (fig. 205) the molar is considerably worn. Nevertheless, it may be seen that the trigonid region is exactly the same as in recent man and that the talonid is also composed of three cusps. As to the general shape the molar is broad as is the rule in recent man, the length-breadth index being 90.2 on the basis of Buxton's measurements.

A comparison of the second molar of *Sinanthropus* with the anthropoids on one hand and recent and Neanderthal man on the other reveals the same fact as in the first molar, namely that the *Sinanthropus* molar approaches the one of anthropoids much closer than that of recent man and that there does not exist a great difference between the latter and Neanderthal man in this respect. More than this, the *Sinanthropus* molar has proven to be even more primitive than *Dryopithecus* by retaining to a surprising degree the original pattern of Eocene primates. The molarisation is much more pronounced in *Sinanthropus* than in the anthropoid group, with the exception of *Australopithecus* which also occupies a special position herein, bringing it into close relation with the hominids.

4. GENERAL REMARKS

The peculiarities of the deciduous dentition complete the picture presented by the characteristics of the permanent dentition. Here and there special primitive features are retained which place *Sinanthropus* closer to the point from which the anthropoids, including *Dryopithecus* and other, have started their special differentiations. It is remarkable that the retention of the primitive features in *Sinanthropus* and the differentiations within the anthropoid group have become manifested in the same manner in the first and second dentition, the first molar of the deciduous dentition also tending to transform into a sectorial type in anthropoids but not in *Sinanthropus*. However, the persistence of the tuberculum molare and the corresponding oblique position of the mesial branch of the root indicate that teeth approaching a kind of sectorial type must have existed in the ancestry of hominids. Adloff (1935) attempted to refute this argument put forth by the present writer in an earlier publication (1934) by claiming that the special position of the root must be considered as an adaptation to the localisation of the germ of the permanent molar which is completely embraced by the branches of that root. Adloff, however, overlooked the fact that this localisation is the same in the second deciduous molar without a tuberculum molare and the oblique position of the mesial branch being developed.

The wrinkles are a characteristic feature of the deciduous molars of *Sinanthropus* as well as of those of anthropoids. On the other hand, the so-called taurodontism, under which an extensive pulp cavity is understood, also occurs in the milk molars of *Sinanthropus* (fig. 303) and Neanderthal man—Gibraltar child (fig. 236). As in the case of the permanent molars this peculiarity is characteristic for the fossil hominids but cannot be taken to represent a specialisation.

Adloff's statement that the deciduous dentition of hominids reveals its genetic independence from the anthropoids is completely disproven by the plain facts presented in the *Sinanthropus* dentition. Exactly the reverse is true. There exist surprising similarities with respect to the special appearance of the canines and the molars. On the other hand very primitive features have been undoubtedly retained in *Sinanthropus*. But the differences which result from this divergency are irrelevant, for it is possible to prove that they are only a consequence of later differentiations of the anthropoids in the course of which the latter lost their primitiveness in this regard. The first molar in *Sinanthropus*, for instance, which exhibits the most striking primitive characters, nevertheless undoubtedly comes closer to the *Dryopithecus* molar than any of the Eocene primates.

II. THE ERUPTION OF TEETH

Since only lower jaws of *Sinanthropus* with erupting teeth have been discovered hitherto, the following statements concern the eruption of lower teeth only. Further-more, it is self-evident that merely the order in which the teeth erupt can be ascertained and that it is impossible to obtain any information as to the time required for the first and second dentition or on the occurrence of a resting period during the latter.

THE DECIDUOUS TEETH

Although much comparative data are available on the eruption of permanent teeth, little is known about deciduous teeth. In recent man the time and the order of their eruption varies considerably. According to Zuckerkandl (1902) i_1 and i_2 make their appearance first, then follows the canine, then m_1 and the last one to erupt is m_2. This order is generally considered to be the usual and normal one. Eichler (1922), however, records that the canine appears after the first molar. Whether essential sexual differences exist in the order of eruption like those observed in the permanent dentition (see below) I am unable to state due to lack of data in the available literature. Hrdlicka (1908) found that no differences existed between American Indian and Caucasian in this respect. Vallois (1934) reports that in the Palæolithic man of Afalou a slight retardation of the canine may be observed.

As to anthropoids Selenka (1899) supplies some information on the order of eruption for all three apes. In chimpanzee the sequence is the same as in recent man, with the exception that the canine is last in erupting. For the gorilla the same holds good but here the canine occasionally may appear before the second molar. The orang follows the gorilla in this respect. In one specimen of *Cercopithecus mona* the order was found to be the same also, namely the canine erupting before the second molar. In the mandible of a very young gorilla of our collection the deciduous teeth are in place, except the canine which is in the stage of erupting on both sides. The only data for monkeys I was able to find dealt with a *Macacus rhesus* in which the canine should appear before the first molar according to Scheff (1913).

Of fossil hominids there are no records available because mandibles of such young individuals have not been recovered hitherto. So much more important is the fact that we are able to make certain statements on the order of the eruption in *Sinanthropus*. In mandible B IV (fig. 299) all deciduous teeth are *in situ* and completely erupted. It is obvious, however, that the degree of attrition is very different. While the first incisor (the second being damaged) and the two molars are more or less worn, the canine is perfectly intact. This condition is fully in contrast to that of mandible B I in which the permanent incisors are already in place, while the deciduous canines are worn up to about one third of their height (figs. 190 and 191). Their integrity in the case of mandible B IV therefore proves that they have undoubtedly erupted as the last ones of the whole series.

Sinanthropus thus follows the great apes in regard to the sequence of the eruption of the deciduous teeth.

THE PERMANENT TEETH

In recent man the order in which the permanent teeth usually erupt is as follows:

$$M_1\ I_1\ I_2\ P_1\ C\ P_2\ M_2\ M_3.$$

There are slight variations of individual character which may occasionally alter this sequence in that one or the other tooth, except M_1 or M_3, cuts through somewhat earlier. But as a rule the sequence just given is fixed for the entire present mankind with only one exception (see below). For more detailed information the reader is referred to the publications by Suk (1919), Degerböl (1931), Grewel (1935).

In anthropoids and in most of the other groups of primates the order of eruption is different in respect to two tooth types (Krogman, 1930, 1931). Schultz (1935) to whom we owe the most recent and thorough investigation of this subject, states: "In all primates, except man, the premolars erupt in rapid and varying succession after the M_2 have been added to the dentition, but before the canines make their appearance." Thus M_2 erupts before the premolars and C after them in the following sequence:

$$M_1\ I_1\ I_2\ M_2\ P_1\ P_2\ C\ M_3$$

It is interesting to note that, according to Schultz, the canine erupts later and slower in males than in females in some of the primates as well as in recent man.

As regards the Neanderthal man Gorjanovic-Kramberger (1906) records in describing the Krapina mandible C that M_2 is already erupted, while m_2 is still in place. In the mandible of the Mousterian youth all three permanent molars are in place together with the left deciduous canine (Klaatsch and Hauser, 1909). According to H. Virchow (1920) the order of eruption in the Ehringsdorf child is as follows:

$$M_1\ I_1\ I_2\ C\ M_2\ P_1\ P_2\ M_3$$

In Neanderthal man therefore M_2 cuts through, in contrast to recent man, before the premolars similar to the condition in anthropoids. On the other hand C in the Ehringsdorf child erupts immediately after the incisors and before M_2, a condition which corresponds to the occurrence in recent man, while in the Mousterian youth C is the last of the permanent teeth to erupt, at least on the one side of the mandible. It is of great importance that the order of eruption of M_2 characteristic for anthropoids and Neanderthal man may also occur in recent man According to Vallois (1934) the sequence of eruption in the Palæolithic man of Afalou is as follows:

$$M_1\ I_1\ I_2\ M_2\ P_1\ P_2\ C\ M_3 \text{ or even } M_3\ C.$$

The same is true for the upper jaw of the young Negroid of Grimaldi according to that author. Drennan (1932) found that in recent Bushman M_2 erupts before the premolars.

In *Sinanthropus* there are two juvenile mandibles which permit judgement on the order of eruption of the permanent teeth. In mandibles B I first described by Davidson Black (1929) and illustrated in my publication on the *Sinanthropus* mandibles (1936) in Plate II, figure 3, and in figure 274 herein there may be seen that the dentition of the right side is:

$$I_1\ I_2\ c\ m_1\ m_2\ M_1\ (M_2)$$

that is to say, the permanent incisors are already in place and the same is true of the first permanent molar, while the deciduous canine and the two molars still persist. However, M_2 is already preparing to erupt, its chewing surface being exposed immediately below the surface of the alveolar process. A skiagram of the mandible (Plate VI, fig. 1 in the above quoted publication) demonstrates besides that picture that M_2 really is situated in the level below the surface, whereas the germs of P_1 and P_2 are still embedded rather deeply within the body of the jaw.

In the *Sinanthropus* juvenile mandible B V illustrated in Plate IX, figures 108 in the same publication (Weidenreich, 1936 *b*) and in figures 265 and 266 herein the permanent incisors and the first premolar of the right side are in place and in addition the second deciduous molar. Both left and right canines are just erupting, the right one being somewhat more advanced than the left. The deciduous canine is already shed. Below the second deciduous molar the germ of the second premolar is still embedded in the mandible. The posterior part of this jaw with the permanent molars, unfortunately, is missing.

From both these mandibles it follows that the order of eruption of permanent teeth of *Sinanthropus* is:

$$M_1\ I_1\ I_2\ M_2\ P_1\ C\ P_2\ M_3$$

This order corresponds to what is known of that of Neanderthal man and of anthropoids, namely M_2 erupts immediately after the appearance of the permanent incisors and before the premolars and the canine. In anthropoids the canine erupts very late as the last before M_3 or even after the latter. In the gorilla material at my disposal the eruption of the canine is completed if the third molar is already in place. In recent man the eruption of the second molar is delayed and that of the canine advanced when compared with the anthropoids. *Sinanthropus* and the Neanderthal group follow the anthropoids as regards the former tooth and recent man as regards the latter.

The reasons for the early appearance of M_2 in *Sinanthropus* and its retardation in recent man are difficult to explain. Degerböl (1931) believes that it has something to do with the upright posture. The posture, however, can hardly be the direct cause for the conditions of this tooth, for *Sinanthropus* and Neanderthal man had already stood erect. I rather think that there must be some connection between the earlier eruption of the C and the later appearance of the M_2 in recent man. For the retardation of C is combined with a special bulkiness of this tooth in all primates, except the hominids. Its development therefore requires a longer time than in a case in which the canine is smaller. The premolars in particular are not only adjacent to the canine but are more or less directly affected by the form and size of the latter as has been shown above. Therefore, they form together with the canine a special group with the incisor on one side and the molars on the other. If the canine is small, the whole canine group develops more rapidly and in this way precedes the eruption of the second molar. Within this group the canine is the last in cutting through in all primates, while in *Sinanthropus* it makes its appearance after the first premolar but before the second one, conforming thereby to the rule in recent man. However, as mentioned above, there is a great variability in all groups so that it is somewhat uncertain to generalize the order on the basis of only one observation. Such a reservation holds good not only for *Sinanthropus* but also for the Neanderthal man.

At any rate, the canine erupts before P_2 in all hominids. This points to the same direction as has been shown earlier, namely that the hominids are derived from a primate stock with smaller canines than those characteristic for the anthropoids of today. It would be of the greatest interest to know whether there is a difference in this respect between the eruption of the upper and lower canines in *Sinanthropus*. According to Röse (1909), Bolk (1926) and Krogman (1930/31) the upper permanent canine erupts in recent man after the premolars and occasionally after the second molar. Unfortunately, the conditions of the eruption of the upper canine are not so well known as those pertaining to the lower one.

In the case of *Sinanthropus* there is an indication that the permanent upper canine, indeed, may erupt after the first premolar. The isolated C' illustrated in figure 38 shows a much less developed root than P^1 illustrated in figure 64 which apparently belonged to the same individual.

III. SIZE AND PROPORTIONS OF TEETH AND SEXUAL DIFFERENCES

In previous chapters repeated reference was made of the size of the *Sinanthropus* teeth, of crowns as well as roots. However, in order to construct a reliable basis for comparison with teeth of anthropoids or hominids, it is essential to have exact measurements. Measurements of only single teeth, of course, have merely a restricted value because they do not make allowance for variations which are in any case quite considerable. But the material of *Sinanthropus* teeth available at present is sufficiently adequate to permit computing of average values, although some types are poorly represented with the result that one or the other value given in diagram form may have to be altered when new material is added.

So as to better demonstrate the results obtained by measurements, it was decided to make use of diagrams. The latter not only permits to compare the single tooth types with each other directly but also with the corresponding types of other primate forms. In addition the actual value of the average measurements concerned can be read off immediately from the diagram which has been traced on millimeter paper. The individual types are given in the abscissa while the ciphers of the ordinate designate the respective values. In order to obtain an adequate formula for the robustness of the crown and root, the length (mesiodistal diameter) is multiplied by the breadth (buccolingual diameter). The so obtained value of course does not express the absolute size of a real cross section of crown or root but is more or less a fictituous one. However, the inaccuracy may be disregarded, since the values in question are applied only for a comparison with other values calculated in the same manner. The average values used in the diagrams are computed from those measurements given in table form earlier in this publication. Unfortunately not all the teeth available were taken into consideration, the reason being that the diagrams have already been sent to the press previous to the new discoveries made in the spring season of this year.

It goes without saying that only such specimens were used for measurements which were not too affected by attrition. This is especially true in the determination of the height of the crown and that of the root. The fact that there is a great difference in the length of the crown of just erupted teeth and those which have been functioning for a considerable time has already been mentioned above. The extent of the attrition on the contact facets which may lower the value for length can hardly be estimated exactly and thus renders this measurement rather uncertain. Of course, this is not only true for the teeth of *Sinanthropus* but also for those of anthropoids and hominids the respective measurements of which are given in the literature.

Measurements of anthropoid teeth used herein for comparison were taken from Remane (1921). But there is one source of error. Remane failed to give the real average measurements and instead gives maximum and minimum values only. The computation of the average on the basis of merely the extreme values is of course incorrect since the real average can hardly correspond to the middle between these extremes. For recent man I first made use of the results obtained by de Terra (1905) and Mühlreiter (1922). Although de Terra's list of measurements includes certain tooth measurements of various races, the majority comprises European races. In the following description the term "recent man" used in quotation refers to de Terra's list. Later Campbell's (1925) work and Drennan's (1929) results on the tooth size of certain races of recent mankind—Australian natives, Japanese, Bushman, European—came to hand and were added in the respective diagrams. As much as I could determine from the available literature, investigations on the differences in size with regard to sex have been carried out by Mijsberg only (1931), at least on a more extensive scale than by others. All these values were compared with those obtained for *Sinanthropus.*

With reference to the measurements of recent man, greater reservation has to be exercised than is necessary in *Sinanthropus*. This is especially true of the values for the height of the crown. However, in this case a probable error may be disregarded, for the crown of the teeth of recent man is, in any case, higher than that of *Sinanthropus.* Thus, attrition in teeth of the former can at best decrease the difference between *Sinanthropus* and recent man but never increase it.

Unfortunately, data on roots are very scarce. In some cases the crown height and the total length of the tooth are recorded thus making it possible to compute the height of the root. For length and breadth of the roots, however, I had to depend upon the relatively inadequate material of our Laboratory composed of prehistoric and recent Chinese teeth.

The values derived for teeth of the Neanderthal group were computed on the basis of measurements made by the respective authors. The Neanderthal teeth included pertain to: Spy, Le Moustier, Ehringsdorf, La Quina, Rhodesia.

1. THE ROBUSTNESS OF CROWNS OF UPPER AND LOWER TEETH

In Diagram 1 values of robustness for upper and lower teeth of *Sinanthropus* are presented. The curve of the lower teeth rises continuously from I_1 to M_2. Nevertheless, three separate groups may be observed which could be distinguished as the incisor group, canine group and molar group. The incisor group is the weakest, followed at a certain distance by the canine group and then again at a greater distance by the molar group. Within the incisor group I_1 is weaker than I_2. Within the canine group the canine itself is the weakest tooth, the P_3 being the stoutest. Within the molar group M_2 is slightly stouter than M_1 while M_3 is clearly weaker than M_1 and M_2.

The curve of the upper teeth shows the same three groups with the only difference that the distances between them are much shorter than in the lower teeth. Within these groups there also exist essential differences: in the incisor group I^2 is weaker than I^1, in the canine group P^1 is slightly stouter than C, while P^2 is weaker than either of them. In the molar group M^1 is the stoutest tooth and M^3 much weaker than M^1 and M^2.

When comparing the curves of lower and upper teeth an interesting fact becomes apparent, namely that only the second premolars and the first molars are of about equal robustness, while all teeth mesialward from P^2 are stronger in the upper jaw and the teeth distalward from M^1 are stronger in the lower one. The masticatory force of the dentition must therefore be stronger in the mesial section of the maxilla and in the distal section of the mandible than in the mesial section of the mandible and the distal section of the maxilla. Furthermore, it is interesting to note that in the upper jaw also P^1 is stronger than C'.

In Diagrams 2-5 *Sinanthropus* is compared with recent and Neanderthal man. Diagram 2 shows the conditions of the upper dentition. The crowns of all teeth of *Sinanthropus* are considerably stronger than those of recent man, except M^3. The decrease in robustness is least in I^1 and greatest in P^1.. As a consequence of this the central incisor in recent man has become the strongest tooth structure of the mesial section of the dentition, that is to say, it is stronger than the entire canine group, while in *Sinanthropus* the latter group exceeds I^1 considerably, and furthermore, that the canine of recent man has become the strongest tooth of the canine group. It is of particular interest that the robustness of M^3 of *Sinanthropus* is not more pronounced than that of recent man which implies that the reduction of M^3 in *Sinanthropus* has already reached the same stage as in recent man, if the inferiority in size of M^3 in comparison to M^1 and M^2 is to be considered an indication of a genuine reduction. It seems that M^3 in its relation to the other molars has the same size and appearance as during any time of the evolution of hominids. Diagram 3 completes Diagram 2 in so far as recent man is concerned. It shows the curves of three different races—Australian, Japanese and Bushman. In all three instances the teeth are much smaller than in *Sinanthropus*, except the molars of the Australian natives, the largest of the group being those of the Australian followed by those of the Japanese and the smallest being represented by the Bushman teeth. In principle the curves are the same in all three races, with the exception of the second molar which is more robust than the first one in the Australian. When compared with the curve of recent man in Diagram 2 which comprises all races, especially European, there may be seen that P^2 is larger than C like in *Sinanthropus*.

Diagram 2 shows in addition that the upper teeth of the Neanderthal group approach closely in robustness those of *Sinanthropus*. The incisors and the second and third molars are even slightly stronger, while the canine group, and especially P^1 is weaker. It is possible, however, that these deviations are dependent upon the relatively scarce material of Neanderthal teeth.

Diagrams 4 and 5 represent the same conditions of the lower teeth. These teeth are also considerably weaker in recent man than in *Sinanthropus* and here the difference is likewise least in the incisor. The difference is greatest in the molars, especially in M_2 and M_3. Therefore the entire curve does not cover such as wide a span as in *Sinanthropus*, that is to say, the teeth have a greater tendency to approach each other in size. The contrast between M_3 and M^3 is very remarkable, M_3 in recent man is only slightly weaker than M_1. The reduction of this tooth in recent man is therefore much less pronounced than in M_1 and M_2 when compared with *Sinanthropus*. If the difference in robustness between M_3 and the other molars so evident in *Sinanthropus* is to be taken as an indication of a real reduction, then the latter did not progress any further in recent man. M_2 is weaker than M_1 in recent man, while in *Sinanthropus* it is stronger. The canine group likewise has undergone a considerable decrease in robustness. However, not the canine but the premolars, especially the first one, are most involved. The lower teeth of the Neanderthal group all remain in midline between *Sinanthropus* and recent man. The incisor group approaches the former closer and the canine group the latter, while the molar group is in between. The three races (Diagr. 5—Australian, Japanese and Bushman) reveal the same conditions as described for the upper teeth, with the reduction being greatest in the canine and the molar groups, except that in the latter the Australian again comes very near to *Sinanthropus*. As to the reduction within the canine group itself, it is interesting that in all three races the canine is weakest like in *Sinanthropus*, while as evident from Diagram 4 in "recent man", that is chiefly European, the canine has become relatively the strongest of the group.

Since the Heidelberg mandible by the majority of authors is considered to represent the most primitive hominid, the robustness of his teeth is compared with that of *Sinanthropus* in Diagram 6. With the exception of M_2 which is much larger than M_1, like in *Sinanthropus*, the curve of the Heidelberg teeth bears a closer resemblance to that of recent man. The teeth are not only weaker than the average *Sinanthropus* teeth but the entire curve is also shortened which implies that the differences between the three groups have become moderated as is characteristic for recent man. The canine group is involved in particular in the reduction, but the decrease in size is more pronounced in the premolars than in the canine, so that the appearance of this group is more similar to recent man.

2. THE HEIGHT OF THE CROWN

In previous chapters special attention was given to the fact that the *Sinanthropus* teeth are very low in relation to their length and that this appearance must be considered to represent a specific and primitive character of *Sinanthropus* when compared with recent man.

Diagram 7 illustrates the curves of the height of the upper and lower teeth of *Sinanthropus*. These curves show that the canine is the highest tooth and that the premolars rapidly decrease in height when nearing the molar. The pre-canine teeth differ in upper and lower dentition. In both sets of teeth the lateral incisor is considerably lower than the canine but whereas the lower central incisor retains the tendency of being low, the upper one is much higher than the lateral one and almost equals the height of the canine. In recent man the upper teeth (Diagrs. 8 and 9) are lower than in *Sinanthropus*. In the case of the Bushman and Australian this difference is very striking (to what extent this lowness may be due to the inclusion of rather worn teeth, I am not able to say). Apart from this, however, the conditions of the upper dentition, as far as the single types are concerned, have changed in two respects. The canine is no longer the highest tooth but instead the central incisor, and the decrease of the post-canine teeth involves the molars to a greater extent than in *Sinanthropus*. The curve of the three races (Diagr. 9) shows that the Japanese corresponds rather closely to "recent man." It is rather strange, however, that in Bushman and in Australian, especially in the latter, the central incisor is by far the highest tooth and the canine does not in any way or only slightly rise beyond the continuously decreasing line of the curve. The upper teeth of the Neanderthal man (Diagr. 8) show approximately the same height as *Sinanthropus*, but there is a great difference between the central incisor and the canine both of which are lower, the first considerably more than the latter. This irregularity which is in contrast to the *Sinanthropus* curve as well as to that of recent man is probably due to the scarcity of material.

The characteristic difference in height between the upper and lower central incisor so evident in *Sinanthropus* (Diagr. 7) also occurs in "recent man" (Diagr. 8), although less pronounced in the latter since the lower canine in contrast to the upper one has preserved its original height (Diagr. 10). The same is true of the lateral incisor and the premolars. The lower premolars are even higher than those of *Sinanthropus*. Diagram 11 showing the conditions of the three races is of particular interest because it demonstrates that the various races differ not inconsiderably in this respect. How far these deviations, especially that of the Australian, are due to the use of more or less worn teeth is difficult to state. Nevertheless, they must be an actuality at least to a certain extent, since the curve of the Japanese as a whole coincides approximately with that of "recent man" in Diagram 10. In the Bushman the general character of the curve is the same, except that all teeth are much lower than in *Sinanthropus* or "recent man." The curve for the Australian also displays a general reduction in height when compared with *Sinanthropus*, making it all the more strange that the first and second molars show such an extraordinary height for which I cannot offer any explanation. The curve of the Neanderthal man (Diagr. 10) coincides in its general character with that of *Sinanthropus* and recent man. The fact that the entire mesial set of teeth is slightly higher even than the average of both these hominids is merely due to the scarcity of material for I only made use of unworn teeth in my comparative measurements. I shall return to the question on the height of the crown in connection with the discussion of its relation to the length.

3. THE ROBUSTNESS OF THE ROOTS

The robustness of the root is expressed by the product of length and breadth measurements immediately below the neck of the tooth. Diagram 12 gives curves of the upper and lower teeth of *Sinanthropus*. When compared with the curves of robustness of the crown (Diagr. 1) it may be observed that the roots of the upper and lower teeth generally are weaker but the differences in robustness between the three groups are less than in the crown, so that the root curves as a whole appear to be more concentrated. (Crown curve of the upper teeth from 80 (I^1) to 147 (M^1)—root curve from 55 to 103; crown curve of the lower teeth from 43 (I_1) to 150 (M_1)—root curve from 23 to 108.) It is quite evident that this concentration is due to the fact that the roots of the incisor and canine groups are stronger in relation to those of the molar group than it is the case in crowns. Furthermore, in contrast to the crowns the roots of both upper and lower canines are strongest in the canine group, whereas in crown the first and second premolars respectively are stronger than the canine.

The robustness of the roots of recent man (Diagrs. 13 and 14) shows the same peculiarity with regard to that of the crown as in *Sinanthropus* as far as the upper teeth are concerned (crown curve from 73 to 126—root curve from 41 to 81). In the lower teeth, however, the concentration of the root curve is much greater (crown curve from 36 to 124—root curve from 20 to 77). This implies that the robustness of the root in recent man is inferior to that of the crown, a condition which is much more pronounced in the lower than in the upper teeth, while in *Sinanthropus* there is no such great difference. The root curve of *Sinanthropus* and recent man in general has the same character for the upper and lower teeth (Diagrs. 13 and 14). Such deviations as there may exist are insignificant. However, there is evidence that the robutness is much less in recent man than in *Sinanthropus*. The difference is smallest in respect to the lower incisors and greatest in regard to the lower molars. Unfortunately, measurements available of roots of the Neanderthal man are too poor to permit an adequate comparison.

4. THE HEIGHT OF THE ROOTS

The curves for the root height of *Sinanthropus* (upper and lower teeth) (Diagr. 15) reveal that the roots of the canines are by far the highest. In the upper teeth that of P^1 is next, while the height of the root of P^2 closely approaches those of the molars. In the lower dentition, the roots of P_2 and M_2 are higher than those of P_1 and M_1 respectively. It is furthermore worthy of note that the root of the lower canine is slightly higher than that of the upper one. In "recent man" (Diagr. 16) there is a very important difference between the upper and lower teeth. The canine of the former possesses by far the highest root, while that of the latter is of the same height as the root of P_2. The average measurements of root height in Diagram 16 were taken over from Black (1902) and they differ considerably from those of Campbell and Drennan derived for the three races (Diagrs. 18 and 20). In all these cases the root of the lower canine is distinctly although not much higher than that of P_2.

In comparing the root height of the upper teeth of recent man with that of *Sinanthropus* a very striking difference may be observed. It consists of an extraordinary reduction in height as far as the teeth from I^1 to P^1 are concerned, while the difference is much less in P_2 and the molars. The greatest difference concerns the canine. In P_2 the deviation is not only slight but in the Australian the height is even greater than in *Sinanthropus*. A comparison of Diagrams 17 and 18 shows that the Japanese have the lowest and the Australian the highest roots. Apart from this, however, there are no essential differences. As to the lower teeth (Diagrs. 19 and 20) the degree and nature of reduction in general is the same as in the upper teeth. Like in *Sinanthropus* the curve has three modes: C_1, P_2 and M_2. The reduction of the root height is greater in the lower canine than in the upper.

The statement that the root height of the upper and lower teeth has been most reduced in the front part of the jaw (I^1—P^2) is in full accord with the change which the mandible of recent man has undergone when compared with that of *Sinanthropus*. I have demonstrated this fact repeatedly in my publication on the *Sinanthropus* mandibles (1936 b) and proven therein that this reduction is in close connection with the development of the characteristic mentum osseum in recent man. That the reduction of the root height of the upper teeth in principle has the same effect upon the formation of the upper jaw has become evident by the recovery of a well preserved maxilla of *Sinanthropus*. The development of the nasal spine and the entire construction of the subnasal portion of the maxilla in recent man appears to be equivalent to the formation of the mentum osseum and is conditioned by the same factor, namely the reduction of the root size. I shall return to this question below.

5. THE DEGREE OF REDUCTION OF TOOTH SIZE IN RECENT MAN IN COMPARISON WITH *SINANTHROPUS*

As has been proven by diagrams and descriptions a great reduction has taken place in tooth size, effecting both crowns and roots during human evolution if *Sinanthropus* is considered as the starting point. Diagrams 21-24 show to what extent the various dimensions of the tooth have been involved by this process. In order to demonstrate it graphically, two methods may be applied: one is to compute the percentage of the decrease of the measurements concerned with *Sinanthropus* as basis. The other one is to compute the percentage of the superiority of *Sinanthropus*, taking the measurements of recent man as basis. In the latter case the single values will be higher than in the former since the basic measurements here are smaller, while the character of the curves will be the same. In Diagrams 21-24 the robustness of crowns and roots for upper and lower teeth are compared. The values used for recent man are computed on the basis of de Terra's measurements or as far as the robustness of the roots is concerned on my own.

Diagrams 21 and 22 demonstrate the decrease in percentage of the upper and lower teeth, of the crown in red and of the roots in black of recent man. In both instances the decrease of the roots is much greater than that of the crown. This is true for all teeth. Nevertheless, with the exception of the first lower incisor, the stronger decrease of the roots is far more pronounced in the front teeth, including P 1, than in the distal set of teeth. In the upper teeth the root of the canine is most reduced, whereas in the lower it is that of P_1. The least affected root in both dentitions is that of the third molar. Moreover, it is interesting to note that the roots of the lower molars are more involved than those of the upper ones. In regard to the crowns it is interesting that the upper lateral incisor and the canine have lost much more in robustness than the corresponding lower teeth, while the molars exhibit just the reverse condition. The curves of the upper and lower teeth therefore run in opposite ways. In the lower teeth the crown of the central incisor is relatively more reduced than the root.

Diagrams 23 and 24 complete the picture presented by the preceding diagrams. They demonstrate in what percentage the crowns (black) and roots (red) of the *Sinanthropus* teeth are more robust than those of recent man. The values correspond completely to those of Diagrams 22 and 23 so that it is not necessary to enter into further details.

6. LENGTH AND BREADTH OF THE CROWN

The robustness of the crowns in the foregoing curves were expressed by the product of length and breadth. However, it is of special interest to know the conditions of either of these dimensions in *Sinanthropus* and recent man.

The curve of the crown length of the upper teeth of *Sinanthropus* (Diagr. 25) displays a very irregular trend. The teeth of the canine group and the lateral incisor are by far the shortest, while the molars and the central incisor are the longest. Among the molars M^1 is considerably longer than M^2 and the latter longer than M^3. The canine is longest within its own group. In "recent man" the character of the curve is exactly the same and the reduction in length has affected the individual teeth to almost the same extent, with the exception of the central incisor and the third molar. That the latter in recent man appears to be longer than in *Sinanthropus* is apparently due to the relatively limited number of *Sinanthropus* specimens. But in any case it proves that M^3 when compared with M^1 and M^2 had reached the stage of its final reduction in length—if it is permitted to use the term "final"—already in *Sinanthropus*.

The curve of the length of the lower teeth yields quite a different aspect in *Sinanthropus* (Diagr. 26). Here the curves rise continuously from I_1 up to M_2. Like in the curve of robustness (Diagr. 1) three groups are recognizable here. The three teeth of the canine group all have about the same length. Within the molar group M_2 is longest and M_3 shortest. In recent man the general character of the curve is again the same as in *Sinanthropus*. The reduction, however, does not show the same extent in all teeth as it may be seen to be distinctly greater in the canine and molar group than in that of the incisor with P_1 and P_2 and M_2 and M_3 reduced more than C and M_1, respectively.

The breadth curve of the upper teeth of *Sinanthropus* (Diagr. 27) is obviously different from the length curve (Diagr. 25), for the former rises continuously from I^1 to M^1—except P^2—and closely resembles the length curve of the lower teeth (Diagr. 26) in this respect. It is remarkable to note that the upper canine being the longest within its group is at the same time the narrowest, while P^1 which by far exceeds its fellow teeth in breadth is considerably shorter than C. The molar group shows the same conditions as existent in the length curve with M^1 being the broadest followed by M^2 and then by M^3. In recent man the general character is again the same as in *Sinanthropus*, except that I^1 is broader than I^2. With regard to the reduction, it is most pronounced in the premolars, especially in the first one, and least in I^1, where it is practically nil, and in M^3.

The breadth curve of the lower teeth (Diagr. 28) like that of the length (Diagr. 26) rises continuously from I_1 up to M_2. Here again we have the three groups slightly separated from each other. Within the canine group the canine is the narrowest tooth and within the molar group the second one the broadest. The curve of recent man has the same character as that of *Sinanthropus*, with the exception that within the canine group the canine is the broadest and within the molar group the first molar, that is to say, that the premolars have become reduced in breadth much more than the canine and the second molar more than the first one.

7. THE RELATION BETWEEN HEIGHT AND LENGTH

It is evident that one of the most characteristic features which permits to distinguish the *Sinanthropus* teeth from those of recent man is the relation between height and length of the crown. As has been shown earlier most of the *Sinanthropus* teeth are low and long while those of recent man are high and short. In order to express the relation, a length-height index was calculated as follows: $\frac{\text{length} \times 100}{\text{height}}$. Values above 100 indicate that the length is greater than the height, while values below 100 indicate the reverse conditions. In Diagrams 29-33 the results are illustrated by curves; the horizontal line crossing the curve represents the 100 mark, that is to say, all teeth below the line are higher than long and all teeth above it are longer than high.

Diagram 29 illustrates the conditions of the upper teeth. It may be seen that in *Sinanthropus* only the molars are longer than high and that all other teeth are higher than long. Within the latter group the canine shows the lowest index, whereas even the central incisor has one that is higher. Both premolars are much lower than the canine. The index of the first molar is higher than that of the second one. It is interesting to note that neither recent man nor Neanderthal man differ essentially from *Sinanthropus*. In recent man the canine index is higher than that of *Sinanthropus*, while it is lower for the premolars. Since reliable measurements of Neanderthal man are so limited, reservation should be excercised when considering the values obtained. This is also true of the values given in Diagram 30. The *Sinanthropus* index is here compared with those of the three races. The curves exhibit that that of the Japanese teeth approaches very closely to the curve of *Sinanthropus* and at the same time coincides almost completely with the curve for "recent man" in Diagram 29, while the index curve for the Bushman and especially that for the Australian deviates considerably. This deviation, however, occurs in a quite unexpected direction involving all indices which turn out to be much higher than the corresponding ones of *Sinanthropus*. This implies that all Australian teeth are lower and relatively longer than those of the latter. While discussing the height curve in Diagram 8 I already called attention to the conspicuously low value of this measurement and suggested that this may be the consequence of making use of unsuitable material, that is to say, of using worn teeth. The slightest wear lowers the height and thereby essentially affects the length-height index by increasing its value. In the case of *Sinanthropus* only such teeth which were practically unworn were used.

It is of considerable interest that the index in question yields quite a different picture in regard to the values for the lower teeth. Diagram 31 shows that the entire curve when compared with that of the upper teeth (Diagr. 29) has *shifted toward the side of the higher values*. This indicates that all teeth are much lower in relation to the length. Thus the entire curve is not only much more elongated than that for the upper teeth but, in addition, exhibits that the premolars which fall below the 100 mark in the curve for upper teeth go above it in the lower dentition. Besides, the incisors and the canine approach that mark closer in the lower dentition than in the upper, whereas the molars, especially the second with values of 170 to 190 are almost twice as long than high. The curve of recent man is quite different in regard to the lower teeth. It is much more concentrated and therefore like that of the upper dentition being shifted entirely toward the side of the lower values, so that the curve at no point coincides with the *Sinanthropus* curve. The values for the incisors and canines are much lower. This inferiority, however, attains extraordinary proportions in the premolars and molars with the former being shifted below the 100 mark. This means that the lower teeth of recent man have reduced particularly in the longitudinal direction, so that now a greater height prevails, whereas the upper teeth were not affected by such a process. The reduction involved premolars and molars to an appreciably greater extent than incisors and canine. It is important that the teeth of the Neanderthal group, except the first molar, show almost completely the appearance true for recent man, that is to say, the characteristic process of reduction here has already reached that stage of development which characterizes recent man. Diagram 32 illustrates the conditions of the three races. Only the curve for the lower teeth of the Japanese coincides perfectly with that of "recent man" (Diagr. 31) while the curve for Australian and Bushman exaggerates the peculiarities of the *Sinanthropus* curve, a condition which, I believe, is also due to the use of not entirely suitable material.

8. THE DEGREE OF ROOT REDUCTION

The decrease in size of the root in recent man is given in Diagrams 33-35. As was done in the case of the crown (see above), the respective values for the length, breadth and height are expressed in percentage taking the averages of *Sinanthropus* as a basis.

The length curve of the upper teeth (Diagr. 33, black) exhibits that with the exception of M^3 all teeth have participated in the reduction: I^2, P^2, M^1, M^2 approximately to the same extent, while P^1 and somewhat less C are by far those most affected. The reduction in length amounts to 44% in P^1 and to 34% in C, in other words, to a third and almost half of the entire length, respectively. For the breadth (red) the conditions are different, namely I^1, M^1, M^2 and M^3 are least involved, while I^2-P^2 most. As to the lower teeth (Diagr. 34) there does not exist such a great difference between the length and breadth curve. The reduction in length is much stronger however, than that in breadth, at least as far as the front teeth and the premolars are concerned. It is least in I_1 and greatest in I_2, the canine group showing a reduction of 26-28%, respectively. The breadth reduction is most pronounced in P_1 with 24%, in P_2 and the first and second molars it is only 17-18%, while I_1 does not show any alteration.

The reduction in height is illustrated in Diagram 35. In the upper teeth (black curve) as well as in the lower (red curve) the reduction is strongest in the front teeth as has already been shown above (Diagrs. 15-20). The lower canine has undergone a decrease of 35%, the upper canine one of 25%; of the upper dentition I^1 with 30% and P^1 with 29% are most affected.

The fact that in recent man there is a great difference between the stoutness of the crown and that of the neck portion of the root is generally known. In *Sinanthropus* this difference is much smaller, because the root is not reduced to the same degree. In order to express these differences graphically, I computed the robustness of the root in percentage to that of the crown for each tooth of *Sinanthropus* and recent man. Diagrams 36 and 37 illustrate the respective curves for the upper and lower dentition, in both diagrams the black curve refers to *Sinanthropus* and the red one to recent man. The curves show that the robustness of the root of the upper canine is 83% of that of the crown, while being only 61% in recent man. For the lower canine the corresponding values are 86% and 65%, respectively. The constriction in the neck region, therefore, must be far more pronounced in recent man than in *Sinanthropus*. The curves show that this constriction is much less in the molars than in the other teeth, with the exception of I_1.

9. THE DIFFERENCE IN SEX

In my publication on the *Sinanthropus* population (1935) I called attention to the fact that the teeth of *Sinanthropus* occur in two sizes, that is, in a large and in a small type. The differences are so great that they can hardly be explained to be due to merely accidental individual variations because variations to such an extent and with such regularity will never be found in relatively so small a population as that represented by *Sinanthropus*. On the other hand it is known that great differences in tooth size due to sex occur among the great apes, especially in gorilla and orang. That the variations in *Sinanthropus* may be attributed to be due to the same factor is supported that his mandibles also occur in two sizes, the large mandibles displaying the large type of teeth and the small ones the other type. In my publication on the mandibles (1936 b) I already referred to this peculiarity which is illustrated by many photographs. It was presumed that the large-sized mandibles belonged to male and the small ones to female individuals. Such a presumption has received further support by the discovery of the new skulls of Locus L on which a brief and preliminary report was published (1937 b). In the latter cases the small teeth were found together with the broken maxilla of the small skull and the large together with the large skull. There cannot be any doubt that the small skull pertains to a female and the large one to a male individual. The proof for this assumption will be given in my forthcoming monograph on the skulls. Figures 263 and 264 demonstrate the differences in size of male and female upper canines and first premolars. For more detailed information the reader is referred to the discussion of this problem in a previous chapter.

Provided that the definition of the large teeth belonging to male and the small ones to female is correct, a comparison of the existing differences in tooth size in recent man due to sex should prove to be of special interest. However, only two investigations on the latter are available which supply reliable measurements of all teeth. The first one is the study by Mijsberg on Javanese (1931) and the second by Janzer on New Pommerian (1927). So as to be able to make a comparison, I computed the robustness of the crowns of the lower teeth of the *Sinanthropus* male and female types, the same of the Javanese and New Pommerian making use of the data supplied by the above quoted authors. The respective degrees of the differences in size are illustrated in Diagrams 38 and 39 by the distance between the curves for the male teeth and that for the female, that is to say, the greater the difference in size the further the curves deviate from each other. The *Sinanthropus* curves are drawn in black, those of Javanese and New Pommerian in red. The curves for the two representatives of recent man show the same appearance as the corresponding curves in Diagram 5. It is worth remarking that the teeth of the New Pommerian in both sexes are more robust than those of the Javanese, although the difference for the female is not as great as that for the male. When compared with *Sinanthropus* both Javanese and New Pommerian teeth are much weaker, with the exception of the first molar of their male types which shows the same value as that derived for the first molar of the female *Sinanthropus*. The third molar also coincides with *Sinanthropus*. As to the sexual differences of the individual teeth it is interesting that they are much greater in *Sinanthropus* than in the two recent races. These differences are particularly evident in the canine and in the molar group, while in the incisors they are insignificant. The differences in the former group are most pronounced for C and P_1 and within the latter for M_1 and especially for M_3.

The sexual differences in size of the *Sinanthropus* teeth are even greater than those in chimpanzee (Diagr. 31) if the canine is excluded, and approach closely those of orang (Diagr. 44).

10. A COMPARISON OF THE SIZE OF *SINANTHROPUS* AND ANTHROPOID TEETH

When the curves of robustness of the *Sinanthropus* crowns are compared with the corresponding curves of anthropoids, it is surprising to find that there are deviations which are not unimportant and may shed some light on phylogenetic questions.

Diagrams 40 and 41 illustrate the conditions in upper and lower dentition of the chimpanzee. The curves of the upper dentition (Diagr. 40) reveal the interesting fact that the incisors and the canine of *Sinanthropus* are less robust than those of the chimpanzee, whereas the premolars and molars of the former exceed quite considerably even those belonging to the male type of the latter. This superiority of *Sinanthropus* is especially true for P^1 and M^1. In the lower dentition (Diagr. 41) such a contrasting behavior is still more evident. The *Sinanthropus* and the chimpanzee curves cross each other directly in P_1. While I_2 of the female chimpanzee shows approximately the same robustness as M_1 (89 : 93), the differences between the values of these two teeth in *Sinanthropus* reach an extraordinary rate (48 : 150). In chimpanzee the robustness of I_2 is 95.7% of M_1, but in *Sinanthropus* the ratio is only 32. In the male chimpanzee the ratio is lower (80.8), but nevertheless still considerably removed from that of *Sinanthropus*. Moreover, it is remarkable that in both male and female chimpanzee P_2 is the weakest tooth, even weaker than the incisors, while in *Sinanthropus* P_2 is the strongest tooth of the entire canine group.

In comparing gorilla with *Sinanthropus* the female gorilla was used because the robustness of the male teeth of this anthropoid predominates to such an extent as to cause the curve to occupy a large field without yielding a more adequate basis for comparison. The curve of the upper dentition (Diagr. 42) reveals that the general character of the gorilla curve is exactly the same as that of the *Sinanthropus* curve and quite different from that of chimpanzee (Diagr. 40). Like in *Sinanthropus*, the three groups (incisor, canine and molar groups) are distinctly separated from each other and each group exceeds the other in size, with the molars considerably in excess of the central incisor and the canine. The smallest tooth here is also the lateral incisor but the premolars are much stronger. The only differences the gorilla and *Sinanthropus* curves show is a general predominance of all gorilla teeth over those of *Sinanthropus*, with the exception of the lateral incisor. With reference to details, the gorilla canine is much stronger than that of *Sinanthropus* and the second molar of gorilla exceeds considerably the first molar of *Sinanthropus*. In both cases the third molar is by far the weakest within the molar group. The curve of the lower dentition (Diagr. 43) corresponds completely to that of the upper in coinciding with the curve of *Sinanthropus* and contrasting together with the latter to the chimpanzee curve (Diagr. 41). There is no crossing of the curves herein like in chimpanzee, the three groups being strictly separated from each other with the incisor group being the weakest, the molar group the strongest and the canine group placed intermediately. The incisor-molar index of robustness (see above) with an incisor robustness of 64 and a molar robustness of 207 amounts to 30.9 which is about the same as in *Sinanthropus* (32.0) in contrast to chimpanzee with an index of 95.7. The differences between the gorilla and the *Sinanthropus* curves, of course, refer to the absolute values since the gorilla teeth are much stronger than those of *Sinanthropus*. However, this is only true of the canine and molar group, for the incisors are only slightly stronger than those of *Sinanthropus*. Another astonishing fact is that P_1 is more robust than the canine, a condition which conforms exactly to that existing in *Sinanthropus*. On the other hand M_3 of the gorilla is the strongest tooth within its group, while in *Sinanthropus* it is the weakest.

It is of interest to note that the curves of the orang dentition (Diagrs. 44 and 45) are intermediary between gorilla and chimpanzee. For the same reason as in the case of gorilla only the female orang is taken for comparison. In orang also the upper and lower front teeth are stronger in relation to the other teeth of the respective dentitions. The curves, therefore, appear more concentrated than in gorilla and *Sinanthropus* but less than in chimpanzee, so that the canine group in both dentitions approaches the molar group. The upper and lower incisors are very robust and come nearer to the canines of *Sinanthropus* than to the incisors, especially in the lower dentition. Like in gorilla and *Sinanthropus* P_1 is stronger than C_1. The molars of the female orang are only partly stronger in the upper dentition than those of *Sinanthropus*, while the lower ones are inferior to those of the latter.

As an example for the conditions of the crown height of the anthropoids well preserved and completely unworn teeth of a female gorilla were used and compared with those of *Sinanthropus*. Diagrams 46-47 show the respective curves for the upper and lower dentition. As regards the former, the curve coincides in its general character completely with that of *Sinanthropus*, the only difference being that all gorilla teeth are higher and that this superiority is more pronounced in the premolar and molar group than in the incisor one. It should be noted that in gorilla and in *Sinanthropus* P^1 is much higher than P^2. The differences in height is considerably greater in the lower dentition (Diagr. 47). Here also it concerns the incisors, especially the central one.

It follows from this comparison of *Sinanthropus* with anthropoids that the conditions of the gorilla dentition are closest to those of *Sinanthropus*, while the chimpanzee stands most removed. The front teeth of this anthropoid probably have undergone a secondary strengthening which must be considered to be a special differentiation. The orang has partly gone the same way but in this case the differentiation has not reached the same degree as in chimpanzee. It is a regrettable fact that the measurements given for the *Dryopithecus* teeth in the literature available are incomplete and only refer to the premolars and molars. In applying the measurements of the lower dentition obtained by Gregory and Hellman (1926) and in completing them by computing an estimate of the robustness of the canine and the incisors, I arrived at the conclusion that the conditions in *Dryopithecus* were like those in gorilla, except that in the former the first molar was by far the weakest tooth within its group.

11. THE ROBUSTNESS OF CROWNS OF THE DECIDUOUS DENTITION

Despite the scarcity of *Sinanthropus* material, I ventured to compute the respective values for the lower teeth and to present them graphically. Diagram 48 illustrates the curve, together with that of recent man (- -). The value for i_2 is questionable because of its defectiveness. However, the line of the curve is very instructive. It reveals that the robustness increases continuously from i_1 to m_2 and reaches its highest values with the permanent first molar. The rise of the curve is constant and relatively rapid. The curve for recent man shows the same conditions, although the teeth are somewhat weaker. Of the Neanderthal group only one or two measurements of incisors and milk molars are available. It may be accidental that these values are higher than those of *Sinanthropus*.

With reference to anthropoids the most important fact is that the *Australopithecus* curve (red straight line) coincides almost completely with that of *Sinanthropus*, with the exception that the first permanent molar is considerably stronger. With respect to the latter peculiarity one must, however, remember that the value for the *Sinanthropus* molar represents an average, whereas that for the *Australopithecus* molar refers to a single individual. The gorilla curve (red interrupted line) agrees with that of *Australopithecus* and thus with *Sinanthropus*, with the exception that all teeth are much stronger. But the general character is the same, that is to say, the incisors are the weakest of the entire set and the teeth following them increase in robustness rapidly and according to their sequence. The chimpanzee curve (. . .) is quite different. It is true that here also the incisors are the weakest teeth, but the differences in robustness between the single types from i_1 to m_1 are insignificant when compared with those in *Sinanthropus*, *Australopithecus* and gorilla. The chimpanzee curve, therefore, runs up almost horizontally to m_1 and then suddenly rises to m_2 and M_1. Thus this curve crosses all the other curves mentioned above. Orang (.—.) shows the same feature with respect to the incisor but beyond that the curve follows the *Sinanthropus*-gorilla trend.

The curves of the deciduous teeth are interesting in several respects. They demonstrate that the particularities concerning the contrasting behavior of the permanent dentition between *Sinanthropus* and gorilla on one hand and chimpanzee on the other are not restricted to the permanent teeth only, but also occur in the deciduous dentition. The stronger development of the front teeth in relation to the other which characterizes the permanent dentition of chimpanzee, therefore, has its analogue in the deciduous dentition. This fact supports the suggestion made above that we were dealing with a special differentiation separating chimpanzee somewhat from the other members of the anthropoid-hominid group. The orang apparently occupies an intermediate position in this respect. The curve of the deciduous dentition furthermore reveals that the differences in robustness between anthropoids and *Sinanthropus* with reference to the permanent canine are here completely lacking and thereby ranging the tooth entirely within the regular order of size between the lateral incisor and the first deciduous molar.

IV. THE RELATIONSHIP BETWEEN DENTITION AND JAWS

In order to appreciate the significance of the special position occupied by the teeth of *Sinanthropus*, we must first obtain definite knowledge of the conditions in question in anthropoids and recent man. Hellman (1919 *a*, *b*) contributed two excellent comparative studies on this problem which deal with the position and occlusion of teeth from the earliest mammalians up to recent man. For the purpose of the present study, however, it seems sufficient to deal with the higher primates only. For the numerous details involved in the problem under discussion, the reader is referred to previous chapters. Here we shall be concerned only with such general questions as the position of the incisors and the prognathism, the form of the dental arcades and the type of occlusion.

A. THE POSITION AND OCCLUSION OF THE TEETH IN SINANTHROPUS

Adloff (1908) in his publication frequently referred to claims that there is a great difference between hominids and anthropoids with respect to the position of the incisors. The incisors in anthropoids should be placed in oblique and forwardly directed position combined with a strong prognathism, while in recent man, regardless of either orthognathism or prognathism, the incisors should at all times meet more or less perpendicularly. The prognathic Australian in this respect is to be as orthognathous as the European. Such feature would be the consequence of a curvature in the longitudinal axis of the incisors. Their roots being bent backward, the axis does not form a straight line but an angle with its vertex at the neck, while in anthropoids the longitudinal axis is either straight or at best slightly curved. Adloff even made the attempt to prove such a conception by supplying several sketches of teeth in his textfigure 5 (p. 110). Nevertheless, I fail to see the differences which he claims to be able to discern. In most cases of recent man as well as anthropoids the axis is formed by a straight line with only the buccal outline of the teeth being curved, a condition which is even more distinct in the latter than in the former. As mentioned above, H. Virchow (1920) observed such curved lower incisors in the Ehringsdorf child and termed this peculiarity as "kyrtodonty". The latter would support Adloff's suggestion. But in *Sinanthropus* such an obtuse angle between crown and root does not exist (figs. 1, 2, 28). The central upper and lower incisors are straight and only the buccal surface of the crown is curved. On the other hand, the stated straightness of anthropoid incisors does not at all constitute as a rule. In chimpanzee as well as in orang curved incisors are found as frequently as straight ones in recent man.

In figures 224-231 sagittal sections through the left central incisor *in situ* together with the corresponding part of the mandible are given. The sections are orientated in the alveolar plane, the longitudinal axis of the incisor being indicated by interrupted lines. The illustrations demonstrate that the axis itself is straight in all cases: gorilla (fig. 224), chimpanzee (fig. 225), orang (fig. 226), gibbon (fig. 227), *Sinanthropus* G I (fig. 228), Heidelberg man (fig. 229), prehistoric Chinese (fig. 230) and recent European (fig. 231). The only differences which do exist concern the buccal outlines of the incisors which are curved in gorilla, chimpanzee, *Sinanthropus*, Heidelberg man and prehistoric Chinese, but straight in orang, gibbon and recent European. The illustrations also reveal another characteristic feature in showing that there is no real difference in the manner in which the incisors are embedded within the alveolar process of the mandibles, regardless whether it concerns an anthropoid or a hominid. The position of the tooth depends exclusively upon the degree of inclination formed by the entire frontal part of the mandible to the alveolar plane. In my study on the *Sinanthropus* mandibles (1936 b) this question was dealt with extensively giving the values of the respective angles.

The angle formed by the longitudinal axis of the left central incisor illustrated in figures 224-231 is given in Table XXVI.

TABLE XXVI

Gorilla	111°
Chimpanzee	114°
Orang	104°
Gibbon	125°
Sinanthropus G I	109°
Heidelberg	104°
Prehistoric Chinese with strong alveolar prognathism	115°
Recent European with orthognatism	92°

From the above it follows that the lower incisors do not take an active part in having a specific form as far as their position in the alveolar process is concerned. This position merely depends upon the special configuration of the frontal part of the mandible and its general inclination towards the alveolar plane.

The same conditions hold good for the upper incisors. Figures 232 and 233 represent sagittal sections through the left central upper incisor *in situ*, together with the corresponding alveolar process of the maxilla both orientated in the Frankfort plane (fig. 232) and in the alveolar plane (fig. 233). The most instructive ones are those of two adult female orangs (*a* and *b*). In both cases the form of the central incisors is the same, the only difference being that of robustness. In case *a*, however, the incisor together with the entire alveolar part in which it is embedded is placed much more vertically than in case *b* where the incisor and its alveolar part are situated almost horizontally. Such a variation in the position of the incisor and in the entire location of the alveolar part can also occur in gorilla and chimpanzee without any effect on the form of the tooth. Figures 232 and 233 c illustrate the conditions of a juvenile male gorilla and *d* those of an adult male chimpanzee. In the former the alveolar process is more erect than in the latter. The fact that the same degree of variability may be found to occur also in recent man is proven by the specimens designated *e*, *f*, *g* and *h* in figures 232 and 233. Both *e* and *h* represent recent male North Chinese, the maxilla *e* is strongly prognathous, while the maxilla *h* is orthognathous. *f* represents a prognathic Australian native, *g* an orthognathic European. In all these cases it is interesting to note differences in the position of the alveolar part resulting from the orientation of the skull, that is to say, if the maxilla is orientated in the Frankfort plane (fig. 232), the alveolar part is much more erect than in the alveolar plane (fig. 233). All this combined demonstrates clearly that the special form of the central incisor is entirely irrelevant both in anthropoids and hominids and is in no way connected with either prognathism or orthognathism.

Virchow (1920) in his study on the mandible of the Ehringsdorf child raises the question on the probable position of the central incisors found isolated. From the appearance of the wear facets which are not orientated in right angle to the longitudinal axis of the tooth but extend upwards on the lingual side causing the cutting edge to be whetted, that author infers that teeth must have had an almost horizontal position and that, therefore, it is difficult to realize the correct aspect of such a maxilla. The same conditions prevail in the upper incisors of *Sinanthropus*. Figure 2 *l* and *m* shows that the wear facet of this tooth extends considerably in oblique upward direction on the lingual surface forming an angle of about 54° with the longitudinal axis (cf. chapter on incisors). In case this incisor were placed in such a position that the facet would come to lie completely within a horizontal plane more or less parallel to the alveolar plane, then its longitudinal axis would form a rather acute angle. Figure 219 representing the entire set of teeth of a female orang and orientated in Frankfort and alveolar planes shows that the wear facet occupies almost the entire lingual surface. Figure 220 which represents the same conditions of another female orang and the photograph of which is given as figure 306 shows that the wear facet is more confined to the lingual-region of the cutting edge. As mentioned above, the alveolar part courses almost horizontally in figure 219, while in figure 220 it is more erect.

How the corresponding conditions may have been in *Sinanthropus* is difficult to say because of lack of maxillæ, especially of the frontal parts. Up to the present only one upper jaw is available which, though slightly damaged, shows the area in question with sufficient distinctness. This upper jaw was recovered (Locus O I) while the preparation of this study was in progress. It will be dealt with in my forthcoming publication on the facial skeleton of *Sinanthropus*. The present study contains a drawing only in lateral view (fig. 345). As is evident in this figure, the alveolar border and the outer surface of the maxilla in the region of the two incisors and canine are restored. But this restoration cannot be to far removed from the original condition, for the lateral incisor is preserved with the entire posterior wall of its socket; the canine is missing, but the complete alveolus is preserved; the central incisor is also missing, but the end of its alveolus is preserved. According to the size of the teeth and the degree of attrition the upper jaw belongs to an old female individual.* Since in jaw O I only the upper end of the alveolus of the central incisor is intact, there is no certain indication as to how far the ridge of that alveolus may have projected forward. Yet, since the entire alveolar process from the end of this alveolus up to the apertura piriformis and the inferior part of this aperture are present, a rather reliable basis for a correct restoration is at hand. According to the special feature of the region in question and to the size of the root of the central incisor the reconstructed outline of the alveolar part is rather less protruding than it may have done originally. In any case, there is no doubt that the subnasal part of the *Sinanthropus* maxilla had projected considerably and moreover, that the entire body of the upper jaw has had the same tendency. The interrupted line in figure 345 indicates where the upper part of the lateral margin of the nasal aperture is broken off. Below this line the margin is intact. In recent man and also in all of the Neanderthal skulls in which this part of the maxilla is preserved the margin bordering the nasal notch falls down almost perpendicularly or even slightly recedes (figs. 304 and 305). But in *Sinanthropus* this margin leads forward and continues gradually within the outline of the protruding alveolar process. These are exactly the conditions which characterize the corresponding region in anthropoids with the only self-evident difference that they are much more pronounced in the latter than in *Sinanthropus* (cf. figs. 345, 306, 305).

Although in this particular specimen of *Sinanthropus* there exists a strong alveolar prognathism combined with a pronounced facial prognathism, the central incisor as judged by the position of the second one preserved *in situ* was rather erect and certainly not placed horizontally as may be inferred from the wear facets of central incisors in other cases of *Sinanthropus*. In order to determine the original conditions, it is of great importance that the wear facets of the lateral incisor of maxilla O I and of the central and lateral incisors of maxilla L II, though strongly worn, do not form such an acute angle with the longitudinal axis as in the slightly worn isolated central incisors, namely only an angle of about 65°. Such an inclination implies a rather erect position of the incisors. As explanation of such obvious different appearance of the *Sinanthropus* dentition, two possibilities present themselves. Either the same variation occurs as found in orang and proven by the existence of a more erect position like the one in figure 220,

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*As the central incisor and the canine of the upper jaw of the adult female Skull II of Locus L are preserved—lacking the alveolar part (fig. 277)—the size and form of these teeth are known, whereas jaw O I lacks those teeth.

and a more horizontal one like that in figure 219, or the change of the angle is only a consequence of a more advanced attrition.

This leads to the problem of occlusion. Most of the jaws of Neanderthal man which permit judgement in this respect show edge-to-edge bite relations of incisors. Hellman (1919 a) infers such conditions from the form and the position of the wear facets of the Heidelberg mandible and the Mousterian youth. With regard to the latter, however, Dieck who carried out the reconstruction of the dentition arrived at the conclusion that overbite relations must have existed (quoted after H. Virchow, 1920 and Weinert, 1925). It is interesting to note that the upper incisors of this Neanderthal type displays the same conditions of attrition as the isolated *Sinanthropus* incisors. H. Virchow (1920) believes that in the case of the Ehringsdorf mandibles edge-to-edge bite relations had been present. Boule (1911/13) suggests the same for the man of La Ferrassie. The upper incisors of the Rhodesia skull exhibit almost the same degree of wear as that of the teeth of the two *Sinanthropus* maxillæ. Thus, it cannot be deduced with any degree of certainty how the conditions of occlusion of *Sinanthropus* were on the basis of those in the Neanderthal man because of the existence of edge-to-edge bite and overbite relations there.

The anthropoids vary in this regard. Hellman (1919 b) stated; "The occlusion of the incisors of the anthropoids, as in the lower orders of the mammals, is expressed either in an edge-to-edge or overbite relation." In his figure 17 he reproduced an orang skull with edge-to-edge bite which corresponds completely to the orang illustrated here as figure 306, the erect position of the central incisors being more pronounced in Hellman's case. Within the material at my disposal overbite prevails in the gorilla, while in orang and chimpanzee edge-to-edge bite may also be present. The statement often made that in recent man overbite relations form the rule is not at all correct. Welcker (1902) found 100% of the Australian aboriginals with edge-to-edge bite and as much as 20% of the population of Germany with the same relation. He believes that overbite should be prevalent in the "Indogerman race" while edge-to-edge bite must be considered a pithecoid character. According to Hellman (1919 b) Amerindians and Eskimo show edge-to-edge bite exclusively. Weinert (1936) in reconstructing *Pithecanthropus* chose overbite conditions without offering an explanation for such a selection.

The lower incisors of *Sinanthropus* as represented in the adult male mandible G I (figs. 283 and 285) have their wear facets parallel to the alveolar plane. Their conditions correspond to those of the upper incisors of the adult female maxillæ L II and O I. Thus, there is no other choice but to suggest that the dentition of adult individuals with strongly worn teeth have had edge-to-edge bite relations. But I doubt whether the same applies to young individuals. The special feature of the isolated upper incisors indicate overbite relations combined with strong prognathism rather than edge-to-edge bite. Hence, I am not certain whether or not a change may take place in the manner of occlusion due to such extremely advanced attrition as occurs in adult individuals of *Sinanthropus* or in recent man, especially in cases in which the type of food had produced a premature and extensive wear. Since the upper incisors are placed more obliquely than the lower ones, the overbite relations must become less pronounced the stronger the attrition. Unfortunately, I am not in a position to undertake thorough investigations on this subject, but I do consider the question sufficiently interesting to attract the attention of dentists. I suspect that Keith's well known statement (1925, p. 670) of an overwhelming majority of edge-to-edge bite in Anglo-Saxon skulls in contrast to an overbite of over 95% in modern English people may partly be explained by the suggestion that in Anglo-Saxon period the attrition of the teeth was much more advanced on account of hard food than it is the case at present, and hence, the original overbite lost in the former, while it persists in the latter. It must be kept in mind that the existence of overbite relations in human incisors can only be determined in such teeth in which the real cutting edge is not worn off too extensively. If the teeth are worn to such an extent as to bring the basal parts of the crowns into direct contact, then conditions of edge-to-edge bite seem to be given. Therefore, canines, especially those which interlook, are much more decisive for the conditions of the front teeth than the incisors.

Indeed, regardless whether edge-to-edge bite or overbite relations exist, the structures and the mechanism of the remaining factors of the masticatory apparatus fail to reveal any fundamental differences. Welcker (1902), it is true, claimed that in cases with edge-to-edge bite ("labidodonty") the marginal line of the alveolar border of the upper jaw and the outline of the chewing surface should describe, when viewed from the lateral side, a regular convex curvature from I^1 to M^3 with the deepest point in the level of M^1—so-called Spee's curve—and that in cases of overbite ("psalidonty") this line should attain an S-shaped form with its anterior section more or less descending. It is very easy to demonstrate that Welcker's conception is without any foundation. Figures 304 and 305 represent two maxillæ of recent man (North Chinese) with strong prognathism and overbite relations which at the same time show a very pronounced convexity of the outlines of the alveolar borders.

Lubosch (1906) made a similar error as Welcker. According to him the overbite relations of the incisors must be due to orthognathism prevalent in recent man, while edge-to-edge bite combined with prognathism should exist in anthropoids. Lubosch even goes further by claiming that he development of the articular tubercle of the temporal bone, so characteristic for recent man, must be considered as a consequence of the acquisition of an orthognathic face, for in anthropoids with very pronounced prognathism this tubercle were almost completely absent. Apparently due to lack of adequate material Lubosch failed to observe that neither orthognathism nor prognathism has anything to do with the occlusal conditions of the incisors in recent man or anthropoids, since edge-to-edge bite (fig. 306) and overbite (fig. 304) may occur in prognathic anthropoids as well as in hominids. Furthermore, the formation of the articular tubercle is also independent from the special configuration of the jaws and from the manner of occlusion. As has been shown above, *Sinanthropus* in spite of a very pronounced prognathism (fig. 345) already possesses a well developed articular tubercle and the same combination is rather common in recent man as seen in figures 304 and 305. For the same reason Hoever's (1912) idea that the formation of the articular tubercle in recent man is a consequence of the adaptation to overbite, substituting the original edge-to-edge bite of anthropoids, must also be considered as erroneous. It is not impossible that the overbite relations in recent man as far as they are found in unworn teeth are due to an unequal reduction of the frontal parts of the maxilla and mandibles. I shall return to this question below.

In the chapter dealing with the canine problem the question had already been raised whether the presence of a diastema can be taken to be an indication of there having existed originally a large canine in a preceding stage of human evolution. Within this chapter it was shown that a diastema had not been present in the lower dentition of *Sinanthropus*, but what the conditions were in the upper jaw could not be ascertained due to lack of material. Since the writing of that statement the upper jaw of Locus O 1 was found (fig. 354) which demonstrates that there is not the slightest indication of the presence of a diastema. Nevertheless, as has already been pointed out, it is impossible to draw any conclusions with regard to the conditions of canines in preceding stages for even in recent anthropoids diastemata in upper and lower jaws may be completely absent, despite the really tusk-like canines (cf. female orang of fig. 306). The fact that such an occurrence is rather common, especially in orang, is proven by Selenka's (1898/99) statement. He found that in the upper jaws of female orangs a diastema was missing in 30% and in lower jaws in 34%. The percentage derived for the male orang is smaller but nevertheless was found to be missing in 18%. The problem on the diastema will be treated more extensively in my forthcoming publication on the face of *Sinanthropus*. Here it may be stated that diastemata in maxilla and mandible are not all of the same nature. A genuine gap does not exist in the mandible between canine and first premolar. In most cases it is feigned because of the far projecting anterior branch of the premolar root which causes the protocone to be more or less removed to some distance from the canine. The less the sectorial type of the premolar is pronounced the narrower the gap. Since the sectorial type of this premolar is a secondary differentiation acquired within the group of anthropoids, the diastema of the mandible is also a secondary acquisition. The character of the diastema of the maxilla, however, is different. Here the gap between canine and lateral incisor, due to the different direction of these teeth, is greater the more these two teeth diverge in their courses. Hence, the diastema is narrower the more erect the position of the incisor (cf. fig. 220) and it is wider the more the incisors take a straight course (cf. fig. 219). As to how much the direction of the teeth exerts an influence upon the configuration of a diastema is revealed by figure 300. In the prosimian illustrated there a wide gap may be seen to exist between the lower canine and the first premolar. In this instance, however, the gap is not a consequence of a sectorial type of the latter tooth—for there is no such type—but only a consequence of the special position of the canine which assumed the appearance of an incisor and, together with the incisor group, formed an almost horizontally extended "comb". The upper canine with its sabre-like form in such case has no relation to the diastema but overlaps the first lower premolar quite far laterally.

B. THE DENTAL ARCADE

The dental arcade of the *Sinanthropus* mandibles has been discussed in great detail in an earlier publication (1936 b). Therein it was shown that this arcade represents a relatively narrow curve, especially in its anterior part, when compared with the respective arcades of recent man or with those of the Neanderthal mandibles. Of particular interest in this respect was the fact that the Heidelberg mandible considered by the majority of investigators as the most primitive hominid type and as characteristic for priminids in general, showed in contrast to the *Sinanthropus* mandibles a more widely curved arcade which scarcely differed from that of recent man. In order to demonstrate this condition again, figure 301 was chosen which gives the occlusal view of the dental arcades of a juvenile chimpanzee (a), of the restored female *Sinanthropus* mandible H 1 (b), of recent man (c), and of the Heidelberg mandible (d). Like in the *Sinanthropus* mandible all the teeth are missing except M_3 but the alveoli are preserved. So as to facilitate a comparison, such mandibles of chimpanzee and recent man were chosen which exhibited the same dental conditions. In the Heidelberg mandible most of the crowns of the left side are broken off, so that the location of the alveoli may also be seen. It is evident in these illustrations that the entire arcade of the *Sinanthropus* mandible is narrow, especially in the posterior part when compared with the Heidelberg mandible or recent man. My publication on the *Sinanthropus* mandibles also contained an occlusal view of the reconstruction of a male *Sinanthropus* mandible (G 1, Plate XII, 1). In mandible H 1 (fig. 301, *b*) the symphyseal part was preserved and thus yielded a reliable basis for the reconstruction of the arcade, while in mandible G 1 this part is missing and therefore the reconstruction based on more hypothetical factors. The mandible K 1 (figs. 287 and 288) and a fragment of another one without any teeth which were subsequently recovered permit a correction of the reconstruction in some respects. It now appears that the distance of the rami estimated in the reconstruction is too wide and that the posterior part of the dental arcade had been narrower still, but that the anterior portion had been correspondingly somewhat wider. With this correction the entire arcade of the male mandible would present approximately the same aspect as the female mandible H 1 (fig. 301, *b*), merely that all the dimensions would be larger.

Hellman (1919 a) supplied diagramatic illustrations of six different arch forms of the anthropoid dentition. The form represented by the *Sinanthropus* mandibles bears the closest resemblance to Hellman's "divergent" form which, according to him, occurs in 85% of gibbon and in 66% of chimpanzee but may also be found in gorilla and orang to a considerable percentage. Yet the actual differences between the hominids and anthropoids cannot be recorded in such diagrams because both show the "divergent" form and the differences mainly concern the width of the arch. As shown in my publication on the *Sinanthropus* mandibles the most characteristic criterion, in addition to the narrowness of the entire arcade, is the even curvature of the anterior section (fig. 301, *b*), while in recent man (fig. 301, *c*) the front teeth form an almost straight line with the participation of the canines which have lost entirely their original character as points of rotation around which the curve courses backward (cf. Hellman).

The regression of the entire front section is a consequence of the reduction in the robustness of the teeth, especially of their roots. Within the *Sinanthropus* stage the primary anthropoid conditions are still preserved. The "divergent" form is here more pronounced in the maxilla than in the mandible with the arcade increasing in width towards its posterior end, while the anterior section exhibits approximately the same degree of curvature as the corresponding section of the mandible.

C. *THE INFLUENCE OF THE REDUCTION OF THE TEETH ON THE FACIAL SKELETON*

The complete dentition of recent man (*a*) and *Sinanthropus* (*b*) is reproduced in figure 239 in natural size. The former is taken from Spalteholtz' atlas, while the latter represents a combination of actually existing tooth types. The orientation of the two series is different, in recent man the chewing surfaces were placed in a straight line, whereas in *Sinanthropus* the boundary between crown and root was used as level.

A comparison of the two dentitions reveals not only the great differences in size of both crown and root but also the relatively greater height of the front teeth of *Sinanthropus*, including the canines. In recent man such differences in height are less pronounced but still existent. The greater height apparently is a consequence of the primary grasping character of these teeth which is combined with a far projecting muzzle. Without a detailed description of the conditions of the upper jaw and face, it is impossible to enter into a discussion of the entire question. Hence, I shall return to this problem in my forthcoming study on the face of *Sinanthropus*.

In my publication on the *Sinanthropus* mandibles (1936 b) and in the study of the development of the chin, (1934) I was able to demonstrate that the formation of the human chin, particularly of that structure which I termed "mentum osseum" must be considered as a direct consequence of the reduction of the alveolar process of the mandible. The reduction of this bony part of the jaw itself is again a direct consequence of the reduction of the front teeth, particularly of their roots (cf. textfigs. 15-29 in above mentioned publication 1936 b, illustrating these conditions.) The reduction of the alveolar part in recent man is manifested by a more or less deep furrow which courses from one side to the other just below the alveolar border and so accentuates the prominence of the basal part, that is to say, the "mentum osseum". H. Virchow (1920) termed this furrow "incurvatio mandibulæ anterior." In *Sinanthropus*, where a mentum osseum does not occur nor a reduction of the front teeth and of the alveolar process, this incurvatio is missing. As the reduction of the teeth and their roots also takes place in the upper jaw, it may be expected that similar conditions will be found to exist there. As strange as it may seem, they have not attracted as much attention as those of the mandibles, at least I was unable to find any reference to this question in the available literature.

The reduction of the alveolar part of the maxilla in recent man is indicated by the "hollow cheeks", so to speak, which may be found in every skull regardless whether it is that of an Australian native, a prognathic Negro or an orthognathic European. The entire facial wall of the maxilla from the nasal bridge downwards and the infraorbital border has sunken in deeply. That which is called fossa canina or fossa incisiva represents only those regions where the process in question appears most advanced (figs. 304 and 305). In anthropoids the facial wall of the maxilla bulges out and projects (fig. 306). One of the most characteristic differences between recent man and anthropoids concerns the special configuration of the facial entrance of the nasal cavity. In recent man there is a prominent nasal spine and—at least in typical cases—a more or less pronounced threshold coursing from this spine toward the lateral border of the aperture and separating the deeper located floor of the nasal cavity from the anterior surface of the alveolar process. In anthropoids the nasal spine is entirely absent or at best indicated by an indistinct elevation and the anterior surface of the alveolar process continues directly into the floor of the nasal cavity. The prominent nasal spine of recent man is apparently the analogy to mentum osseum of the mandible, representing, so to say, the "chin" of the maxilla. As a consequence of the reduction of the alveolar process of the maxilla these parts emerge and form the proper frame of the facial construction like the basal part of the mandible.

Figure 345 demonstrates that *Sinanthropus* in this respect resembles the anthropoids much more than recent man. The alveolar process bulges out, the canine ridge is well developed and takes part in the formation of the lateral border of the nasal aperture. It is true that the median region itself is only partly preserved in maxilla O 1, but a nasal spine cannot have been present because the floor of the nasal cavity does not show any elevation toward the median plane up to the nasal opening of the left incisive canal. Neither is there an indication of a threshold bordering the floor of the nasal cavity. The floor is completely even and separated only by a simple and not elevated brim from the anterior surface of the alveolar process. These peculiarities—more detailed information will be given in my forthcoming publication—together with the prognathic character of the entire maxilla mentioned above show that the configuration of the latter as far as it depends upon the conditions of the teeth corresponds to that of the mandible and that *Sinanthropus* represents in this respect also a very primitive type of hominid.

Finally, with regard to the topographical position of the *Sinanthropus* molars in relation to the jaws there are no essential differences either between *Sinanthropus* and recent man or between the former and the anthropoids. It is interesting to note that in the male *Sinanthropus* mandible G I the third molar is partly concealed behind the anterior border of the ramus (cf. Plate X, 7 b and Plate XI, 1 of my study on the mandibles, 1936 b). This condition is common to anthropoids and also occurs in recent man. Nevertheless, it is interesting that in the Heidelberg mandible, despite the bulky character of the entire jaw and the extraordinary breadth of the ramus, the third molar is located in front of the ramus. In the upper jaw a similar landmark is represented by the level in which a perpendicular drawn from the middle of the zygomatic process of the maxilla meets the molars. In *Sinanthropus* maxillæ O I and L II this line meets the distal border of the first molar. There is no general rule, however, neither in anthropoids nor in recent man. Occasionally, the line meets the middle of the first molar or the mesial portion of the second.

D. THE DECIDUOUS DENTITION

Due to the fact that a maxilla with deciduous teeth has not been recovered up to the present, it is impossible to make any statement on the occlusal conditions of the infantile jaws. The mandible B IV, however, with a complete deciduous dentition permits conclusions to be drawn at least on the conditions of the lower jaw.

It was shown in figure 69 and Table VI in my study on the *Sinanthropus* mandibles (1936 b) that the angle of inclination (63°) formed by the front part of the jaw with the alveolar plane is about intermediary between that of the chimpanzee child (54°) and that of Chinese child (75°) with similar conditions in dentition. That figure, however, also demonstrates that the central incisor of the *Sinanthropus* mandible is much more erect than is true in the chimpanzee child, being even somewhat recurved like in recent man (cf. Plate VIII, figs. 3-5 of the mandible publication and fig. 299, *b* herein). The wear facet forms a right angle with the longitudinal axis of the incisor and the so preserved cutting edge of the lateral incisor exhibits the same manner of attrition. From this appearance it may be deduced that edge-to-edge bite relations existed. Unfortunately, it is impossible to draw any conclusions on the angle at which the upper incisors had been embedded within the maxilla. Edge-to-edge bite relations exist in all cases with deciduous dentition of orang, gorilla and chimpanzee among our material. The number, however, is too small to permit the statement as that such manner of occlusion actually prevails within the deciduous dentition of the great apes. With regard to recent man investigations on the occlusal relations in deciduous dentition of the various races seem to be lacking. In the material at my disposal I found overbite in all cases of European and Chinese jaws. As to the conditions within the Neanderthal group we have no information due to lack of material.

The fact that the deciduous canine of the infantile *Sinanthropus* mandible B IV is separated from the lateral deciduous incisor as well as from the first deciduous molar by a rather wide gap had already been pointed out in my publication on the *Sinanthropus* population (1935). Plate I of the latter contains photographs of *Sinanthropus* mandible B IV (fig. 2) compared with a chimpanzee mandible (fig. 3) and a North Chinese child (fig. 1) both of which exhibit a similarly complete deciduous dentition. In *Sinanthropus* and in the chimpanzee child wide gaps may be seen to exist, whereas in the human child the teeth are crowded together and do not show any gaps. Gaps may also be observed in the photograph of the mandible B V illustrated in figures 299 *a*-c and 303 in this study. Unfortunately, I am not able to determine whether this arrangement of the deciduous teeth may be considered typical for *Sinanthropus* or whether it represents an exceptional case because the mandible described above is the only one equipped with an entirely deciduous dentition. The *Sinanthropus* mandible B I (illustrated in Plate II, figs. 1-3 of the mandible publication) does not reveal any gaps; it must be taken into account, however, that in this case the deciduous incisors have already been replaced by the permanent teeth. Among the orang and chimpanzee mandibles at my disposal the original gap between the lateral deciduous incisor and the canine either disappears or becomes narrower if the permanent incisors have erupted. It is possible that the same conditions existed in *Sinanthropus*.

The diastemata separating the *Sinanthropus* deciduous canine from its adjacent teeth are not of equal width, the gap between the canine and the first molar with a width of 1.7 mm being broader than that between the canine and the lateral incisor with a width of 1.3 mm. Contrary to this, the anterior canine gap in the great apes seems to be slightly wider than the posterior one. The posterior gap occupies the same position as the diastema of the permanent dentition. The latter must be considered as a formation correlated with the strong development of the upper canine and the first premolar. Of the deciduous dentition of anthropoids the upper canine interlocks in a similar manner. Therefore, the existence of a diastema in the lower deciduous dentition of *Sinanthropus* suggests that the upper canine must have been much stronger than in recent man. An upper deciduous canine of *Sinanthropus* has as yet not been recovered. The anterior gap, however, demands a different interpretation. Its existence cannot depend upon an interlocking upper tooth. Since this gap disappears after the eruption of the permanent incisors, its only purpose seems to be to reserve an adequate space for the permanent teeth. Such a view is supported by the fact that there is a narrow gap of 0.9 mm width between the first and second deciduous molar also (cf. fig. 299). In any case, it is remarkable that the deciduous dentition displays in regard to these gaps the same conditions as in anthropoids, while in recent man —at least as a rule—those gaps are absent.

It may be that the development of the gaps has something in common with the transformation of the dental arcade during the second dentition as demonstrated in the study on the mandibles (pp. 108-112, 1936 b). It possibly indicates that, despite the human character borne by *Sinanthropus* in regard to that transformation, there have been similar conditions as those in anthropoids in an earlier stage of evolution.

V. *SINANTHROPUS* TEETH COMPARED WITH SUCH OF DOUBTFUL NATURE

The discussion herein will deal with certain doubtful findings the taxonomic character of which is being debated and upon which new light may be shed by a comparison with the *Sinanthropus* material. For it must be borne in mind that with the discovery of the *Sinanthropus* teeth and the recognition of their primitive nature most of the old problems appear in a different light. The earlier comparisons have the disadvantage that teeth had been considered as prototypes of primitive hominids which in the light of the new material are no longer entitled to such special positions. The teeth of the Heidelberg mandible have played a great role in this regard, and, so to say, a fatal one. I have no intentions of going into details regarding all these questions and the literature connected therewith, but consider it sufficient to merely discuss the problems on the basis of the newly acquired facts.

A. PITHECANTHROPUS ERECTUS

It is only appropriate to begin this comparative study with the description of those teeth which were found together with the skull cap of *Pithecanthropus* and attributed to belong to the same individual by their discoverer E. Dubois. Only recently (1937) E. Dubois arrived at the conclusion that the skull cap must be considered to belong to a giant gibbon and not to a real hominid as was believed a certainty after the discovery of *Sinanthropus*.

Dubois did not refer to the teeth particularly when making the above statement, but since in his earlier study (1924) he was convinced that the teeth belonged to the same individual, there is no other way but to classify the teeth into the same category, that is to say, they must be attributed as also belonging to a giant gibbon. In figure 242 two of the three *Pithecanthropus* teeth are copied after Dubois' illustrations and casts at my disposal. Dubois determined *a* as representing P_1 rt and *b* as M^3 rt. In this connection it should be noted that the first lower premolar of a gibbon in all cases represents a typical sectorial tooth similar to that of *Dryopithecus* in figures 240 and 241. The *Pithecanthropus* premolar (*a*) does not bear the slightest resemblance to such a form; instead, it shows in all its details the characteristic features of a hominid tooth. Figure 133 illustrates furthermore a right third upper molar of *Symphalangus syndactylus*. Its shape and pattern—the difference in size may be disregarded since Dubois considers *Pithecanthropus* a "giant" gibbon—is completely different from the *Pithecanthropus* molars. According to Remane (1921) it may occur, though rarely, that the metacone or the hypocone are strongly reduced in Hylobatidæ but at any rate characteristic for this primate order is that the cusps are well developed and represent high and distinctly circumscribed cones, while on the other hand wrinkles are completely missing. The *Pithecanthropus* molar reveals exactly the reverse condition. The third *Pithecanthropus* tooth, a third or second upper molar, resembles the tooth illustrated in figure 242 *b* so closely in size, shape and pattern that it is of no significance here whether it concerns a second or a third molar. Thus, neither the premolar nor the molars rate the classification as belonging to Hylobates. For it must be supposed that a "giant gibbon" must also have the same types of teeth characterizing the entire group, unless that term implies nothing more than a totally imaginary form.

As to the question whether or not the three teeth belong to the same individual it may be stated that certain authors (Hrdlicka, 1930, and Adloff, 1931) contend such a possibility. R. Schwarz (1930) and Adloff (1931) already called attention to the fact that the premolar is much less worn than the two molars. As evident from figure 242 this is perfectly true. The first lower premolars erupt much earlier than the third upper molar, so that exactly the reverse feature may be expected if both teeth belong to the same individual. There is another important contrast between the two teeth, however, which excludes any possibility of regarding them as fellows of the same dentition. Adloff (1931) already pointed out that the premolar is far too small in proportion to the bulkiness of the molar. Both these teeth are copied in the same size in figure 242 (2/1). There is no primate which shows such a ratio in size between P_1 and M^2 or M^3 like that in the case of *Pithecanthropus*. As may be seen from the diagrams the premolars of the hominids are smaller than the molars, but in anthropoids there is not such a great difference in the robustness of the crowns in question (confer Table XXVII giving the robustness (length × breadth) of the crowns of P_1 and M^3 together with computations of the ratio between the two teeth).

TABLE XXVII

Robustness (length × breadth) of crowns of P_1 and M^3

		P_1	M^3	Ratio
Gorilla ♀	average	150	208	72.2
Orang ♀	"	113	133	85.2
Chimpanzee ♀	"	82	101	81.1
Symphalangus synd.	"	42	55	76.3
Symphalangus synd.	—	33 (min.)	73 (max.)	45.2
Sinanthropus	average	87	108	80.5
Recent man in general	"	59	106	55.7
Recent man Australian	"	69	123	56.1
Recent man Bushman	"	52	84	61.8
Pithecanthropus	—	57	173	33

The respective values are those derived from the diagrams, the values for *Symphalangus* are taken from Remane (1921), those for *Pithecanthropus* from Dubois' (1924) measurements. The table reveals that in anthropoids and *Symphalangus* the robustness of the crown of P_1 in average is somewhat more than three-fourths of that of M^3 and the same holds good for *Sinanthropus*. In recent man the ratio is much less, the robustness of P_1 here being somewhat more than one half of M^3, apparently as a consequence of the relatively much stronger reduction of the premolar. In *Pithecanthropus*, however, P^1 only represents a third of the robustness of M^3. The values derived show that the robustness of the premolar completely falls within the range of variation of recent man, a condition which corresponds to the entire appearance of this tooth, while the robustness of the third molar is rather similar to that of a recent female gorilla. In order to demonstrate that such a combination is impossible, the minimum value for a *Symphalangus* premolar in relation to the maximum value for a *Symphalangus* third molar (measurements after Remane) are also given. Even in this rather improbable case the robustness of the premolar is only slightly less than one half of the molar. Since the robustness of the remaining molar of *Pithecanthropus* amounts to 166 (instead of 173 for M^3) the difference may be disregarded. In any case the values prove not only that the premolar and the molars cannot belong to the same individual, but also that they can neither belong to the same species. The outlines of the crowns of a first lower *Sinanthropus* premolar and a third upper *Sinanthropus* molar are placed side-by-side in figure 242 *a'* and *b'*. Both teeth represent the small type and probably belong to female individuals. A comparison with the corresponding *Pithecanthropus* teeth shows the conditions of size which actually exist (*a'* and *b'*) and those which are imaginary (*a* and *b*).

Most of the authors are unanimous in considering the first premolar (fig. 242 *a*) of *Pithecanthropus* as being a human tooth. But in view of its palæontological character and its alleged relationship to the skull cap of *Pithecanthropus* there arises the question as to whether there is any resemblance to the corresponding tooth type of *Sinanthropus*. I have been able to prove (1937 c) that the *Pithecanthropus* skull cap approaches the female *Sinanthropus* Skull II Locus L to such extent that both have to be taken as representatives of a closely related hominid group with *Pithecanthropus* representing the somewhat more advanced type. The *Pithecanthropus* premolar is undoubtedly smaller than any of the *Sinanthropus* premolars on hand. The values for robustness of the small (female) type of the latter even range from 74 to 81, while those for that of *Pithecanthropus* amount to only 57. In addition to this difference the pattern of the *Pithecanthropus* premolar is quite different from that of the *Sinanthropus* premolar. The attrition is relatively slight and rather confined to the buccal moiety and the protoconid, so that the region of the metaconid is hardly affected. A comparison with the first *Sinanthropus* premolars (figs. 79, 80, 82, 83, 84, 86, 87, 328) exhibits that the pattern of the chewing surface lacks the numerous features which characterize *Sinanthropus*. The premolar bears the closest resemblance to that of the Mousterian youth (fig. 94) but with the remarkable difference that the latter shows an asymmetry in favour to the talonid pattern (cf. fig. 329), while in the *Pithecanthropus* premolar the trigonid portion is longer than the talonid one. Therefore, this premolar either belongs to a recent man type or at best to a Neanderthal type, although it is not very characteristic for such a type. In any case, this tooth does not have the slightest resemblance to a *Sinanthropus* premolar and, therefore, my belief that it does not belong to the *Pithecanthropus* skull cap.

The upper molars of *Pithecanthropus*, especially the third one, illustrated in figure 242 *b* offer a rather different aspect. The premolar is too small when compared with *Sinanthropus* to the same extent as the third molar is too large. Its robustness amounts to 173, while those of *Sinanthropus* range from 90 to 126 with an average of 113. With regard to the length-breadth relation the index in *Sinanthropus* ranges from 116 to 128 with an average of 122.5, while that of the *Pithecanthropus* molar amounts to 135.4. This difference is too small, however, to be of significance. Of greater importance is the fact that the buccal, lingual and distal surfaces of the crown are convex to such an extent as has never been observed in *Sinanthropus* or in hominid molars but a condition which exists in orang. On the other hand, though not as pronounced as in the *Pithecanthropus* molar, the triangular form in consequence of a considerable reduction of the metacone is very common in orang. But the most decisive factor is the pattern of the chewing surface; the cusps are very low and indistinct and the entire surface as far as it is not worn off covered by wrinkles which in total appearance (size, arrangement and abundance) show the characteristic peculiarities of orang wrinkles (compare figs. 125, 126 and 243 *a* and *b*). R. Schwarz (1930) already noted this feature.

The roots are rather robust and strongly divergent and the buccal branches fused. These peculiarities, however, are not so specific as to make a certain diagnosis possible, with the exception that their appearance coincides with that of the anthropoid roots.

An unprejudiced examination of the *Pithecanthropus* molars will leave no other choice but to attribute them as belonging to an orang. Indeed, such a definition would coincide with Turner's first impression (1895) when he examined the molars, as well as with Topinard's (1895) opinion. Both these authors had a great fossil orang in mind which may have lived in Java at the same time as *Pithecanthropus*. G. Miller (1923) compared the molars in question with those of 16 recent Borneo orangs and found that they failed to exhibit any feature which would separate them generically from an orang or, on the other hand, indicate a relationship to man. The only differences from recent orang, according to that author, being that they show a bulging out of the crown beyond the level of the roots mentioned above and the wider angle of divergence of the latter. Gregory and Hellman (1923) and von Koenigswald also emphasized the almost complete conformity between the *Pithecanthropus* and the orang molars. The entire question received a new aspect with the knowledge of the existence of a fossil orang within the same region and contemporary to *Pithecanthropus*, thus confirming Turner's and Topinard's suppositions. E. Dubois (1924) himself did not overlook the fact that the shape of the crown of the third molar "presented a striking resemblance to some orang-utan teeth which I collected in caves in Central Sumatra" and goes on to say: "Besides, such a shape of crown of M^2 is frequently met with in the orang-utan." These orang teeth collected in caves by Dubois apparently belong to a fossil orang since most of the fossil orang teeth described in the meantime by C. C. Young (1932), W. C. Pei (1935) and von Koenigswald (1935) and mentioned herein were derived from caves in South China (Yünnan and Kwangsi). The possibility that it concerns only one species of orang is rather remote since von Koenigswald already determined the presence of a giant orang (*Gigantopithecus blacki*). The fossil orang species of Java may possibly have those peculiarities which differentiate the *Pithecanthropus* molars from those of recent orang.

Hence, the three teeth attributed to *Pithecanthropus*, that is to say, considered by Dubois as belonging to the brain case, can no longer be brought into any connection with the latter. The molars are those of a fossil orang. Since the premolar bears such close resemblance to that of recent man and on the other hand is so different from that of *Sinanthropus* and in view of the close relationship between the *Pithecanthropus* and *Sinanthropus* skulls, this tooth must also be excluded from the genuine *Pithecanthropus* material.

As the premolar undoubtedly represents a recent man type, it is not surprising to learn that the tooth collected by the Selenka expedition in the vicinity ot Trinil and described by Walkhoff (1911) has been determined to also belong to a recent man type. This specimen known as the tooth of Sondé is a left lower molar, probably a first one, and so worn that most of the finer details of the pattern have become obscure. Walkhoff considers it to be a typically human tooth and was unable to define any particular primitive feature.

A discussion of the geological conditions and an explanation for the presence of recent man teeth in Trinil layers, however, is beyond the scope of my study.

B. THE PILTDOWN TEETH

Earlier (1936) I was able to demonstrate that the Piltdown mandible did not bear the slightest resemblance to the *Sinanthropus* mandible in so far as the specific features were concerned. I pointed out, in accordance with Friederichs (1932), that all those peculiarities which determine the real individuality of this jaw were characteristic of the female orang.

This study is only concerned with teeth. The question is whether they are hominid or anthropoid teeth, in the latter case they would correspond to the character of the Piltdown mandible. The majority of investigators who contended the human character of this mandible, as for instance G. Miller (1915, 1918) and Ramström (1916) considered the teeth to be anthropoid (chimpanzee). The difficulty of the whole problem, however, is not so much a morphological one as it is one touching the fundamental conception of the homogeneity of the animal organisation. The one who believes in the possibility of a mandible belonging to a skull with all the characteristics of recent man, despite its great ape appearance, will not hesitate to admit the combined occurrence of an anthropoid-like tooth and a human brain. In any case it is of interest to know whether the Piltdown teeth resemble those of *Sinanthropus*, the representative of the most primitive hominid known hitherto, and if so, in what respects.

Four teeth have been attributed as belonging to the Piltdown man. Two right molars, one first and one second molar were found embedded within the mandible. An additional isolated tooth recovered subsequently from the same site was taken to represent a right lower canine and to belong to the same jaw. Still later a left, probably first lower molar was found at the same site but not at the same place and also brought into direct connections with the Piltdown findings. The reader is referred to the extensive literature dealing with these finds.

As to the two molars *in situ* (fig. 216) Smith Woodward (1913) described them as being distinctly human. But since these molars are embedded within a mandible which, regardless of the various views held, differs considerably from that of recent man and approaches closely that of an anthropoid, one may expect that the molars, provided they really represent human teeth, bear a closer resemblance to those of *Sinanthropus* rather than to those of recent man.

The size of the crown cannot be determined here with any degree of accuracy because the original teeth are not available for measurements and also because such measurements as have been made by the various authors lack conformity. Therefore, the following discussion as far as the size is concerned must be regarded with every reservation. According to Hrdlicka (1922) for instance, the length and breadth of the two molars is the same, namely 13.0 mm and 11.0 mm respectively, the robustness being 143 mm for both M_1 and M_2. According to Woodward

(1913), however, the measurement for M_1 is 109 (11.5 × 9.5) and for M_2 120 (12.0 × 10.0). The latter values are rather inferior to those derived for the *Sinanthropus* molars. For these in *Sinanthropus* range from 120 to 171 in M_1, and from 136 to 168 in M_2, if only molars *in situ* are taken into account. On the other hand Diagram 41 reveals that the robustness of the Piltdown molars coincides completely with the average of a male chimpanzee with 109 and 123, respectively. As a matter of fact, the average values of 132 and 148 derived for the female orang (cf. Diagr. 45) are superior to the Piltdown values, if Woodward's measurements are correct, but this smallness of the Piltdown molars is in complete accord with the size of the mandible which is inferior in all its dimensions when compared with that of a female orang of today (Friederichs, 1932; Weidenreich, 1936 b). The length-breadth index of the Piltdown M_1 is 82.7 and that of M_2 83.5 (according to Hrdlicka's measurements 84.6 in both molars). These values are decidedly inferior to those of *Sinanthropus* with a variation from 91.1 to 97.2 for M_1 *in situ* and from 95.9 to 102.3 for M_2 *in situ*. But it must be kept in mind that this index may drop to a very low level in Neanderthal molars and even in recent man and on the other hand may reach a rather high level in anthropoids, especially in the orang, so that the length-breadth index cannot be considered a reliable criterion for classification. According to Hrdlicka's measurements M_2 is of the same size as M_1, while according to Woodward and the casts M_2 is somewhat larger than M_1. The latter conditions may also be observed to occur in *Sinanthropus*. As to the trigonid and talonid indices the trigonid of M_1 with an index of 86.2 is much broader than the talonid with an index of 78.0 on the basis of Gregory and Hellman's measurements (1926), while the corresponding values for M_2 amount to 85.6 and 81.6. The difference of 8 index-units between trigonid and talonid in M_1 and of 4 units in M_2 is much higher than in *Sinanthropus* and thus represents a distinct indication of the anthropoid character of the Piltdown molars.

The measurements give only a partial answer to the question whether the Piltdown molars are hominid or anthropoid but the pattern of the crowns and certain other structural features may be a better aid. Unfortunately, the teeth are rather worn, so that only a few details may be observed. These, however, suffice for a diagnosis. In figure 216 M_1 and M_2 are copied on the basis of the original drawings in Dawson's and Woodward's publication (1913), and photographs reproduced by Gregory and Hellman (1926) and finally casts. Both molars are characterized by the distinctness with which the talonid cusps are separated from the other cusps, not only on the chewing surface itself but also on the outer sides of the crown. This isolation of the individual cusps which has been preserved despite the strong attrition is a very specific feature and never met with in a hominid molar, even not in *Sinanthropus* where the cusps are still more distinct than in recent man. A glance at the *Sinanthropus* mandibles (figs. 283, 284, 288) or the isolated molars with approximately the same degree of attrition as the Piltdown molars (fig. 141 *o*, 147 *o*) will show that the bases of the cusps are much more fused. The isolated condition is especially true of the hypoconid which, in addition to the feature in question, also reveals a very characteristic basal form in its cross section produced by wear—"typical wedge-form"—according to Ramström (1916). Moreover, there is in both molars a deep depression corresponding in its position to the talonid basin and from this pit fine fissures meander between the bases of the talonid and the trigonid cusps. A similar arrangement will not be found to occur in hominid molars, whereas it is quite common in molars of an orang. Two lower orang molars (M_1 and M_2) are copied and illustrated in figure 342 after Selenka (1898/99). These molars represent the teeth of a female orang with almost the same degree of attrition as the Piltdown molars. The illustration was selected at rand m from many similar drawings. It may be noted that the hypoconid displays exactly the same form as in the Piltdown specimens. The fact that Selenka's drawings illustrate typical forms is confirmed by the majority of teeth of adult female orang. The extensiveness of the isolation which the cusps of the orang molars show in advanced attrition is all the more surprising because, according to the general viewpoint, the orang should be provided with the lowest and the least distinct cusps. In reality this is not so and, as has been shown above, the development of the cusps in the fossil orang is still more pronounced than in present-day orang.

That the Piltdown molars are those of an orang-like ape is furthermore demonstrated by the arrangement of the cusps and their relative size (compare fig. 216 with fig. 342). The reader is referred to Friederich's remarks on this point (1932). An additional support is given by the inner structure of the molars. As revealed by figure 317 which represents a copy of Underwood's (1913) skiagram of the Piltdown mandible the pulp cavities of the two molars are rather large and high, that is to say, that they show the conditions of "taurodontism". Earlier herein it was shown that such a phenomenon cannot be taken as a distinctive criterion. I was able to prove, however, that, *in contrast to the frequently stated opinion, taurodontism may also occur* in anthropoids, especially in the female orang. Figure 320 is such a skiagram of an adult female orang of today. A comparison of figure 320 with the Piltdown skiagram of figure 217 will show that the degree of taurodontism is exactly the same in both cases. More than this, the comparison also shows that the constriction in the neck region is of the same extent in both types. The difference existing is that the roots of the Piltdown molars are lower than those of female orang, a condition which is only natural because the orang mandible chosen for comparison is much higher and bulkier than the Piltdown mandible. On the other hand the two branches of the Piltdown M_1 have the same appearance as those of the female orang, the mesial branch being lower and narrower than the distal one in both cases.

Thus, there is not the slightest doubt that the two molars of the Piltdown mandible (*in situ*) are typical anthropoid molars with the closest resemblance to those of female orang of today. The latter statement is in complete accord with the results obtained for the Piltdown mandible (1936 b). G. Miller (1915, 1918) and Ramström (1916) both are of the opinion that the molars cannot be considered to be those of a hominid but attributed them to a chimpanzee. It is true, that apart from the presence of "taurodontism" which is not peculiar to a chimpanzee tooth, the Piltdown molars reveal a certain resemblance to the teeth of this ape, but the similarity only concerns the general anthropoid features while the wear of the crowns does not permit an accurate differential diagnosis.

The left lower isolated molar attributed to a second individual of "*Eoanthropus*" by Woodward (1917) was also described as a human tooth. Gregory and Hellman (1926) in illustrating the right molars of the mandible—their figure 21—placed that molar which they considered to represent a first one, side-by-side with the first molar of the mandible for the purpose of demonstrating the identity of the two teeth. Figure 216 illustrating M_1 It is a copy of Gregory and Hellman's reproduction completed by a cast at my disposal. A comparison of the left and the right molar, however, shows that they are not identical. The left molar is not only somewhat larger, though Hrdlicka derived the same measurements for this molar as for M_1 rt and M_2 rt, that is, 13 × 11, but it also lacks the features which characterize the right side. Although the degree of attrition is approximately the same, there is no trace of an isolation of the cusps on the chewing surface nor on the outer side of the crown; furthermore, there is no indication of a "wedge-form" of the hypoconid nor of a talonid basin or of wrinkle-like fissures. The tooth merely shows the presence of five cusps, a condition without significance. According to Gregory and Hellman's measurements the trigonid is to be considerably broader than the talonid, but the cast at my disposal shows only a slight difference between the former and the latter (94.4 against 91.8). In accordance with Friederichs' definition, I consider the left Piltdown molar a human tooth. It is true, that its length-breadth index (after Hrdlicka 84.6 and after Gregory and Hellman 85.7) is rather low but such low indices also occur in recent man. On the other hand, it is interesting that in contrast to the mesial surface of the Piltdown molar the distal one does not show a distinct contact facet as is common of first molars, especially of those in which the attrition of the chewing surface has reached an advanced degree. The absence of this peculiarity fully explains the relatively great length of the tooth. In any case, it has no specific resemblance to the *Sinanthropus* molar.

The most debated specimen of the Piltdown teeth is the canine. I shall confine myself to the demonstration that this tooth does not bear the slightest resemblance to a lower canine of *Sinanthropus* nor to that of recent man (cf. also Marston, 1936). Figure 213 represents a copy of the Piltdown canine after Dawson and Woodward (1914).

A comparison of the description given for the *Sinanthropus* canine and figures 50-56 will show that not one of the features characterizing that *Sinanthropus* tooth may be found in the Piltdown canine. Both crown and root are entirely different not only in details but also in their general shape. The Piltdown canine is certainly not a hominid tooth. This statement is all the more remarkable because the Piltdown molars in certain features at least approach the hominid molars so closely that various authors were induced to determine them as being human. How could it be possible then that the molars are "distinctly human", while the same mandible is different in all respects?

Yet the Piltdown canine neither resembles any anthropoid canine, not even that of a fossil orang. Figure 61 illustrates a right lower canine of a fossil female orang. Although the lingual surface of the Piltdown canine—also considered to belong to the right side—is strongly worn, yet it may easily be seen that the tooth has nothing in common with the orang canine. Here again the same contrasts may be observed, namely, the molars are orang-like in all their peculiarities, while the canine fails to show any similarity.

It was claimed (Lyne, 1916) that the canine is a deciduous tooth. Such an assumption likewise seems incorrect. Figure 188 illustrates such a canine of *Sinanthropus* and figure 192 that of a fossil orang. A comparison with figure 213 will show that in these cases also there is not the slightest resemblance.

The most conspicuous peculiarity of the Piltdown tooth is that the entire lingual surface, strongly worn from the tip of the crown to the base, represents a rather smooth concave surface. The latter appearance does not fit a canine, lower or upper, because its opponent can in no case abrade the entire lingual surface only. Keith (1925) attempted to evade this difficulty by suggesting that in the case in question the canine had already been shifted into straight line with the incisors. But even in such a position that manner of attrition cannot have taken place. For, provided the tooth actually is a lower canine, as generally accepted, the occlusal relations of the incisors must then have been such of an exaggerated undershot bite. The far projecting structure of the front portion of the mandible, however, is absolutely in contrast to such an assumption. Adloff supposed that the tooth may represent a lateral upper incisor of an anthropoid. Figure 244 contains skiagrams of a lower canine of *Sinanthropus* (*a*); that of a small orang (*b*) and that of a lateral upper incisor of the same ape (*c*). When comparing these illustrations with the one of the Piltdown canine (fig. 213 *s*) it becomes obvious that in the latter case we are dealing with a very young tooth which must belong to a much younger individual than the one to whom the molars belong.

To determine whether this Piltdown tooth actually represents a canine or some other tooth type is beyond the task of this study. It is sufficient to have proven that the tooth has no relationship whatever to the mandible and still less to the fragments of the brain case.

Hence, my conclusion that not one of the teeth of the Piltdown remains represents a primitive hominid type like *Sinanthropus*. The two right molars *in situ* belong to an orang-like anthropoid (*Boreopithecus dawsoni*, cf. Friederichs. 1932) and the left isolated one is a recent human type. The same is true of the fragments of the brain case which were found later together with this tooth.

C. "HOMO KANAMENSIS"

In his work on the stone age races of Kenya Leakey (1935) refers to a fragment of a mandible composed of the alveolar part from the first right molar to the first left premolar, in which only the first and second premolars of the right side are preserved. The crowns of the first right molar, those of all the incisors and of both canines are broken off but the roots are preserved in their sockets. According to Leakey the premolars also are not in a perfect state of preservation. Although that author admitted that neither the mandible, except in its robustness, nor the canines differ in principle from those of recent man, yet he established a new species of *Homo* whom he called *Homo Kanamensis*. This discrimination is based upon three features involving the premolars. The first, according to him, being that the crown is not separated from the root by a constriction in the neck region, the second that both premolars are separated from each other by a wide gap and the third, that, as the skiagram shows, the pulp cavity of the root is relatively large.

It requires no special proof that neither one of these three features nor their combination within one mandible justifies the establishment of a new species of *Homo*.

The absence of a constriction in the neck region which is so characteristic for the teeth of *Sinanthropus*, especially also for lower molars, will occasionally be observed even in recent man (fig. 146 *a*-*c*) and with reference to the gap between the two premolars Leakey himself reproduced a skiagram of a *Homo sapiens* mandible (Plate V, D) in which the width of this gap is at least as much as that of the debated case. As regards the roominess of the root canals, its variation is so great and dependent upon so many circumstances that it certainly does not represent a reliable criterion for such a far reaching differentiation. Rebel (1931) reproduced in his figure 2498 a longitudinal section of a lower premolar of recent man showing a pulp cavity considerably larger than those of the Kanam teeth.

Therefore, as far as the teeth are concerned there is no significant reason to separate the Kenya man from recent man.

VI. THE SPECIFIC CHARACTERISTICS OF THE *SINANTHROPUS* TEETH

Werth (1928), in summarizing all the facts available then, made the following statement with regard to the human dentition: "Fossil man does not show any decisive differences in any respect when compared with recent man. All the characteristics of the dentition of fossil man fall within the range of variation of present mankind", and in speaking of the dentition went on to say: "The result is always the same and implies that the dentition of man represents a very ancient type, so to say, an Early Tertiary form." The facts supplied by more recent discoveries have seldom been more distinct than in this case in proving the erroneous conception upon which such suppositions were based.

The view that plain structures and smooth surfaces of recent man represented genuine primary conditions was suggested by the relatively simple pattern of the teeth of *Parapithecus* which is generally considered a direct forerunner of the anthropoids and, therefore, a type not too far removed from the starting point of the hominid stem. The belief is that hominids, that is to say, recent man, have strongly preserved the original primitiveness, while it was lost in the stem of anthropoids in consequence of a more and more developed specialization. The entire literature contains remarks considering that the simple character is of a primitive pattern, while the complicated one of secondary nature; but it has been completely overlooked that a *priori* the reverse course is just as likely, namely that a complicated pattern in an earlier stage of evolution may be lost and then replaced by a simple one. The dentition of mammals offers very instructive examples for such possibilities; it would be sufficient if we bear in mind the phylogenetic line: Carnivora—Archæoceti—Cetacea.

Long before the discovery of *Sinanthropus* there were many indications pointing to the secondary character of the simplicity of the tooth pattern in recent man. Each additional recovery of a not too worn tooth of the Neanderthal man revealed the same feature, namely a much more complicated tooth pattern than that in present mankind. But with an astonishing obstinacy attempts were made again to minimize or to neglect the phylogenetic significance of those features or—a particularly favored method—to eliminate the representatives of such types by considering them as mere specializations removed from the main line of evolution leading up to recent man.

The discovery of the Heidelberg mandible with his recent man-like dentition is chiefly responsible for that deplorable confusion. As I have shown elsewhere (1936 a) there is no evidence in palæonanthropology that geological age and morphological primitiveness must be considered as evolving hand in hand under all conditions and for all sites throughout the entire world. On the contrary, we have indisputable proofs that exactly the reverse relations may exist. It is no longer doubted, for instance, that the European Neanderthal types of the last interglacial period represented by the Ehringsdorf, Steinheim and Sacropastore skulls, exhibit despite their great geological age the characteristics of more advanced hominids than the "classic" Neanderthal man of La Chapelle-aux-Saints or la Ferrassie, though the latter belong to a later geological period than the former. But it is not quite appropriate herein to enter into a discussion as to how the apparent dilemma may be solved.

It has been shown in the description of the individual tooth types of *Sinanthropus* that an uninterrupted line of evolution leads from the *Sinanthropus* stage to that of recent man with the teeth of the various members within the Neanderthal group occupying an intermediate position, even though generally the latter have already approached the recent man stage more than that of *Sinanthropus.* Therefore, there cannot be the slightest doubt that *Sinanthropus* actually represents a direct forerunner of recent man. Not only can this fact be proven with all the data furnished by the available skeletal parts but also and in particular by the conditions of the teeth themselves. In all such cases in which a certain number of teeth of a given type is at hand, the variation within *Sinanthropus* himself embraces a continuous line from a very primitive stage to a rather advanced one. The lower premolars furnish the best examples in this respect. The first premolar illustrated in figures 79 and *272 b* is, as mentioned above, so anthropoid-like that if it had been recovered as an isolated tooth and not within the *Sinanthropus* mandible B I, the majority of experts would have certainly suspected its belonging to a hominid. This would have been even more true of the second premolar illustrated in figures 97 and 273 *b* of the same mandible. Then again, other *Sinanthropus* premolars like the first one of figures 272 *c*, 83 or 84 and the second one of figures 273 *c*, *d*, 101 or 103 have already lost some of their characteristic primitive features and closely approach the teeth within the Neanderthal group, even though they retained a number of primitive peculiarities. The same variability occurs also in the lower molars, as has been shown above. On the other hand, such primitive teeth like the premolars of mandible B I are fellows of lower incisors (fig. 27) which hardly differ from those of recent man. This feature of the *Sinanthropus* teeth corresponds to that of recent man, with the exception that in the latter the variations display the reverse tendency, a condition which may also be found in Neanderthal teeth. The fact that *Sinanthropus* falls within the direct line of human evolution is furthermore evident by the absence of such particularities of teeth which could be taken as expressions of specializations. As has been shown in the discussion of wrinkles and taurodontism both these features represent characteristics of primitive hominids. For they occur in the dentition of *Sinanthropus* as well as in that of all the other members within the Neanderthal group—except the Ehringsdorf adult whose teeth do not show taurodontism—and persist to a certain extent in palæolithic man and in certain races of present mankind (Bushman, Eskimo, Amerindians). The frequently stated view that the peculiarities in question must be considered as secondary specializations lacks any substantial foundation.

The change in human teeth in the course of evolution, as far as it can be deduced from a comparison between the *Sinanthropus* stage and that of recent man, concerns the size, shape and special pattern. As may be seen from the diagrams, the reductions of size affects the roots more than the crowns and the reduction in crown size is more pronounced in the canine and molar groups than in the incisor. The roots decreased particularly in height, especially in case of the front teeth and up to the second premolar, whereas the crowns in length, especially in the lower canine and molar groups. This manner of reduction produces particularly in the latter case a conspicuous change of the entire shape. The teeth concerned appear to be higher and shorter. The canines, the upper as well as the lower, have become much more slender in recent man, the lower canine even displaying a more pointed aspect. The talonid in the lower premolars which is well developed in *Sinanthropus* has completely disappeared, and the originally asymmetrical form with a relatively large mesiodistal diameter has become symmetrical with the latter diameter considerably smaller than the buccolingual one. A similar process took place in the lower molars in which the tendency towards reducing the length is manifested partly by a gradual diminution of the metaconid in addition to a different arrangement of the cusps (plus pattern instead of the original *Dryopithecus* pattern) and partly also by elimination of the distal cusps of the talonid.

The change in size and shape is combined with a progressive simplification of all patterns which finally resulted in completely smooth tooth surfaces. One of the most characteristic features of the *Sinanthropus* teeth is the abundance of accessory ridges and folds. The latter cover the lingual or chewing surfaces of the teeth; their arrangement being adapted to the special structure of the tooth. Not less important than the presence of these wrinkles is the persistence of a well developed cingulum or its differentiations in all of the teeth. Both these features have become so obscure that the real nature of their remainders within the standard type of recent man can only be recognized by tracing them back to the *Sinanthropus* stage.

These processes of transformation taking place in the dentition during the phylogenetic evolution of hominids must be considered as partial occurrences of the numerous alterations of the entire skull. As far as the facial skeleton is concerned it consists of a reduction in massiveness and especially in the length of the jaws. The reduction affects particularly the frontal parts of the jaws, thereby causing a corresponding decrease in the height and robustness of the front teeth (chiefly of the roots) including the canines and the first premolars. An additional consequence is a diminution of the alveolar parts of the maxilla and mandible. The process affecting the maxilla leads to a special formation of the facial skeleton which may be designated as "hollow cheeks" and that of the mandible to the formation of the chin (mentum osseum). Simultaneously, the upper and lower dental arches become shortened and to a proportionate extent widened in their frontal portions.

One of the most interesting facts revealed by the *Sinanthropus* material is that the reduction of the teeth within the entire Neanderthal group already has reached an advanced degree not too far removed from recent man; the structural peculiarities of these teeth bearing a closer resemblance to those of recent man than to those of *Sinanthropus*. The massiveness of the roots has been less affected. Unfortunately, the state of preservation of the teeth of the various specimens of the Neanderthal group is different. Most of the teeth (La Chapelle-aux-Saints, La Ferrassie, Gibraltar, Heidelberg, Rhodesia, Spy, Steinheim) are strongly worn as to make a detailed comparison impossible. This being the case, the judgement is confined to no more than the general shape. But the teeth of the Ehringsdorf and Gibraltar children, those of the Mousterian youth and certain of the Krapina remains are well enough preserved to permit a determination to a certain extent of the exact position occupied by them in the course of evolution leading from *Sinanthropus* to recent man. Of all those teeth only the second lower premolar of the Ehringsdorf child (fig. 105) shows some resemblances to the *Sinanthropus* type of mandible B I (fig. 97). But as is evident from a comparison of the two teeth this similarity is restricted to a mere general approach as far as the location of the trigonid and the formation of a talonid are concerned, while great differences remain in the details of these structures, even though the Ehringsdorf premolar germ is in exactly the same stage of ontogenetic development as the one of *Sinanthropus*. This example may be sufficient to demonstrate again the fact how much more primitive the teeth of *Sinanthropus* are than those of any of the Neanderthal group. Even the famous Taubach tooth (fig. 153) which was at first considered to be rather chimpanzee-like by Nehring (1895) does not reveal, as has been shown above, any of the specific primitive features which may suggest its independent differentiation from the other representatives of the Neanderthal group. When comparing the teeth of the Ehringsdorf child with those of the mandibles of Spy or Heidelberg, it will become apparent that the same variability which characterizes the *Sinanthropus* dentition also occurs in the dentition of the Neanderthal group. The only difference is that in the latter the range of variations has already extended into that of recent man, while in *Sinanthropus* it does not even reach the lower boundary of the latter, with the exception of the lower incisors. That these eeth retained their almost unchanged character in the entire course of evolution of man may be explained by the fact that the variation in the character of lower incisors within the entire anthropoid group is rather small, their general appearance, at least, being almost identical in great apes and hominids.

As has been proven by the *Sinanthropus* dentition, every statement made in regard to the teeth of the Neanderthal group, for instance of the Heidelberg mandible, as being typical representatives of very early hominids is incorrect. Hominids, within the preceding stage of evolution to the Neanderthal group, approach the anthropoid group so closely in the general appearance as well as in details of their teeth that such differences as may exist between them are entirely of secondary nature when the dentition as a whole is compared with that of other primate groups. The view that the simplicity of tooth morphology in recent man and partly also within the Neanderthal group, in contrast to the morphology of the anthropoid teeth, must be considered a really original primate character, proves to be a legend.

The position to be attributed to the *Sinanthropus* dentition within the system of the primate group resulted from the general and special characters of the individual tooth types. The description of these types and their comparison with those of anthropoids at the beginning of this study incontestably prove that the frequent claim of fundamental differences existing between the dentition of hominids and anthropoids has no foundation whatever, and the claim could only be made before the discovery of *Sinanthropus* when really primitive hominid remains had not been available for comparative study. Adloff (1908-1937), an ardent supporter of the hypothesis on the complete independence of hominids, considers all features in which the hominid teeth resemble those of anthropoids not as real anthropoid or "pithecoid" characters but as such which should be peculiar to all primitive primates and, therefore, retained to a certain extent in anthropoids also. This view is entirely erroneous. For there is no specimen of the living stock of primates nor of the fossil primate remains known hitherto which would resemble the primitive hominids as represented by *Sinanthropus* in dentition as closely as the fossil or recent anthropoids. It is irrelevant whether prosimians or Platyrrhinæ or the various forms of Catarrhinæ, including Hylobatidæ, are used for comparison, for in each case the special appearance of the *Sinanthropus* teeth will show the essential characteristics of the anthropoid teeth. For details the reader is referred to the extensive description contained in the preceding chapters. It may be sufficient to point out again to the lower premolars, especially the second one, and the first lower molar as the most characteristic molar type. The first lower molar of *Sinanthropus* in its typical form (cf. fig. 165) has the following features in common with the anthropoids:

1. the second molar is slightly larger than the first one (Diagr. I).
2. the length is greater than the breadth (fig. 165).
3. the trigonid is broader than the talonid (fig. 165).
4. there are six distinct cusps (fig. 165).
5. the metaconid is the largest cusp and longer than the protoconid and the hypoconid is smaller than the mesoconid (fig. 165).
6. the cusps are arranged in such a way that three of them occupy the buccal moiety and three the lingual (fig. 165).
7. there is a distinct *Dryopithecus* pattern (fig. 165).
8. there are typical wrinkles in a characteristic location and arrangement (see all figures illustrating unworn molars).
9. a cingulum and even indications of stylar cusps are retained on the buccal surafce (figs. 140 and 148).
10. the enamel descends lower on the buccal than on the lingual side (figs. 139 and 142).
11. both branches of the root are straight and divergent (fig. 142).
12. the mesial branch of the root is lower and narrower than the distal branch and its apex is subdivided into two portions (fig. 142).

All these twelve peculiarities of *Sinanthropus* molars are also more or less pronounced in those of anthropoids but not in any other primate group in such a combination.

As to the second lower premolar which has been discussed in great detail above, it may be sufficient to recall its surprising similarity not to an imaginary primate form but to the premolar of the great apes, especially of the chimpanzee and orang (compare fig. 97 with figs. 102 and 108).

That which applies to this premolar and to the lower molars also holds good for the other teeth. Another excellent example showing how close the relationship really is between *Sinanthropus* and the anthropoids is presented by the upper central incisors; the differentiation of their lingual surfaces bears exactly the same character in all cases (compare figs. 3 and 4 with figs. 14, 15 and 17) but will not be observed in such special manner in any other primate group.

Of course, certain differences may be found to exist in all teeth; yet the differences between *Sinanthropus* on one side and the anthropoids on the other are not greater than those which exist between the various genera of the anthropoids themselves. It is a constantly repeated habit, when debating the relations between the hominids and the great apes, to regard the latter as a kind of morphological unity, for instance, when speaking of "the" canines or "the" first lower premolars of anthropoids. Such an expression implies that these teeth exhibit exactly the same appearance throughout the different representatives of this primate group. Nothing is further removed from the actual condition than such a viewpoint. With respect to the canines, it is generally known that those of female individuals are considerably smaller, that is to say, lower and less robust than those of males. The general character of the anthropoid canines when compared with those of the hominids may be determined just as well on the basis of a female tooth as on that of a male. Earlier herein attention was called to the fact unknown hitherto, that the lower canine of the fossil orang from the Yünnan cave (fig. 61) in its general appearance approaches the upper canine of *Sinanthropus* (figs. 38 and 39) so closely that most of the differences are almost obscure. The first lower molar which commonly is a pure sectorial type in anthropoids may even in recent apes, especially in the chimpanzee (cf. fig. 81) occasionally adopt the form of a non-sectorial type, thus lessening the differences from *Sinanthropus* (fig. 79) to a minimum.

Even admitting that those cases as the one of the chimpanzee premolar are rather rare, their occurrence alone proves that the common form merely represents the fixation of an extreme variation in the direction toward a sectorial type which had not been peculiar to anthropoids originally. The conditions of the canine of the fossil orang support this conception as far as the canines are concerned. On the other hand the considerable reduction in size of crown and root which both upper and lower canines of *Sinanthropus* have already undergone in a preceding stage of evolution (cf. chapters on canines and premolars) makes it evident that the size of the canines of the forerunners of *Sinanthropus* cannot have been too different from the anthropoid type represented by the female fossil orang.

Thus, even such teeth of *Sinanthropus* which show considerable divergency from the common anthropoid type will reveal their relationship to the latter. The simplest explanation given above is to assume that anthropoids, in respect to the tusk-like character of their canines and the sectorial type of the first lower premolar, have undergone a specialisation exaggerating their primary conditions, whereas they have become gradually diminished in hominids. This divergence, however, cannot be used as proof against a direct relationship between anthropoids and hominids, since it only involves the canine and the first premolar. The conformity between the primary hominid and anthropoid types, as may be deduced from the appearance of the two examples just described, in any case seems to be much more pronounced than that between the corresponding teeth of *Sinanthropus* and any other primate groups. It is true, certain primates are provided with relatively small canines but the smallness alone is not a decisive factor. In *Parapithecus*, for instance, which is considered as the most primitive catarrhine and anthropoid type known hitherto, the lower canine is lower than the lateral incisor but considerably higher than the first premolar. Despite this primitive character, however, the *Parapithecus* canine differs in its entire appearance from the *Sinanthropus* canines much more than the latter from the canines of anthropoids, especially from that of the fossil orang mentioned above. The attempt, therefore, in pronouncing the hominid canine fundamentally different from those of the anthropoids is frustrated by the very fact that no primitive canines are known to approximate hominid canines as those of the anthropoids, at least as far as their more generalized types are concerned.

Neither has the first premolar of *Sinanthropus*, even though it does not represent a sectorial type, a special resemblance to the first premolar of *Parapithecus*, and the same is true of the second premolar. The latter tooth, as it is represented in *Sinanthropus*, already exhibits a considerably advanced degree of molarization, so that the differences between the *Sinanthropus* premolar and that of *Dryopithecus* are minimal, while the corresponding tooth of *Parapithecus* yields an entirely different aspect. As was correctly emphasized by Mollison (1924), caninization of the first and molarization of the second premolar which differentiate the two premolars within the group of the later Catarrhinæ so strongly had not yet set in in *Parapithecus*. Such a primitiveness is also revealed by the robustness of the teeth of the lower dentition of *Parapithecus* (Diagr. 49), the canine together with the first premolar being weaker than the second premolar, a condition which is also characteristic for hominids (cf. Diagr. 5). Apart from this, *Sinanthropus* approaches the anthropoids incomparably closer than any primitive fossil or recent primate.

When judging only by the nature of the dentition and its similarity or dissimilarity with other primates *Sinanthropus* must, undoubtedly, be ranged within the group of anthropoids. The question which arises in this connection concerns only the special place to be attributed to him. Since Huxley's time chimpanzee is considered that species which displays the closest affinity to man with reference to its general external appearance and to the peculiar character of all the body parts. For the dentition, however, this only holds good to a certain degree. It has been possible to demonstrate with reference to the first and second lower premolars that those of the chimpanzee reveal the same character. But in other teeth the conditions are quite different. The canines and upper molars of *Sinanthropus* rather resemble those of the fossil orang. The lower molars and the upper incisors exhibit certain features which are most pronounced in the gorilla. On the other hand, with reference to the relation of robustness between the front teeth and the molar, the chimpanzee differs from *Sinanthropus* in principle, while the gorilla shows the same conditions (cf. Diagr. 40-43). Thus, these facts leave no other choice but to admit that *Sinanthropus* as representative of primitive hominids occupies a proper position within the anthropoid group.

The probable nature of the relation between *Sinanthropus* and *Dryopithecus* has already been discussed above. Gregory (1922) and O. Abel (1928) both consider *Dryopithecus* not only a direct forerunner of the gorilla and perhaps of the chimpanzee stock, but also an ancestor of the hominids. I fail to agree with such a viewpoint. I doubt that all fossil material which has been combined under the name *Dryopithecus* really represents a morphologically and phylogenetically homogeneous anthropoid type. For such *Dryopithecus* specimens of which mandibles with canines and the first premolar are preserved must certainly be excluded from the ancestry of hominids. Both these teeth in all cases already display the characteristic differentiation of the tusk-like appearance of the canine and the sectorial type of the premolar. To trace *Sinanthropus* back to *Dryopithecus* would suggest that the former had passed a stage in which he had been equipped with a typical tusk-like canine and a sectorial type of the first premolar and that both features had completely been lost again. It seems to me that the other explanation I offered in connection with the canine problem to be the more probable one. Anthropoids in an early stage of evolution may have been provided with canines stronger and higher than those of *Sinanthropus* but in general appearance they could not have been too far removed from those of the latter. The same was probably true of the premolar in so far as a non-sectorial type existed in this case. In *Sinanthropus* and hominids this primary type has undergone a partial reduction, while in anthropoids, including *Dryopithecus*, both these teeth become differentiated in a special manner. In this respect one fact is of great interest. While in *Parapithecus* no essential difference in appearance of the first and second lower premolar can be recognized, there is a great difference between these teeth not only in the case of typical anthropoids with a specialisation of the first premolar toward the formation of a sectorial type, but also in those cases as represented by *Sinanthropus*, where the latter type did not occur. A comparison of figure 79 with figure 97 shows that both *Sinanthropus* teeth differ in the special pattern of their chewing surfaces in about the same degree and direction as the corresponding teeth of the chimpanzees of figures 81 and 102. This peculiarity certainly cannot be interpreted as a general primitive primate character but as one which indicates that its belongs to a higher group with the already acquired tendency to develop the two premolars in different directions. This condition is the same in typical anthropoids, with the only difference that the first premolar becomes a sectorial type.

Thus, it is evident that the anthropoids divided into two branches. One of them being characterized by an exaggerated tusk-like development of the canine combined with a sectorial type of the first premolar as represented by *Dryopithecus*, its relatives and their descendants; it includes all anthropoids with a strongly heteromorphic canine group. The other is defined by a less advanced differentiation of the three members of the canine group and includes the anthropoids with a more homomorphic canine group. This group includes *Sinanthropus*, other hominids and *Australopithecus*. As to the relation between *Dryopithecus*, other anthropoids and hominids, I agree, therefore, with Osborn (1928) who assumes that the general stem of the Anthropoidea divides into two main branches, with one leading to the hominids and the other to the anthropoids proper.

Repeated reference was made earlier herein to the dentition of *Australopithecus africanus* Dart, including discussions of the close relationship between *Australopithecus* and *Sinanthropus*. It may be stated again that the first upper permanent molar of *Australopithecus* (fig. 115) corresponds to that of *Sinanthropus* (fig. 113) not only with respect to the general shape and pattern of the chewing surface but also to such details as the connection of the metacone with the distal portion of the protocone. The general conformity in the first lower permanent molar (figs. 156, 165, *o*) is obvious, though the pattern of *Australopithecus* is less complicated and certain primitive features such as the differentiation of the cingulum are more pronounced here. The great similarity between *Australopithecus* and *Sinanthropus* may also be observed in the deciduous dentition. As has been shown, the relative breadth of the first and second molars of *Australopithecus* (fig. 201) is of no significance since *Sinanthropus* (and chimpanzee) also exhibits a considerable variation in this feature (cf. figs. 194, *o* and 199 m_1). Of importance, however, is the entire pattern of these molars, and especially the persistence of details of the trigonid (fig. 201). The relationship in size between the front teeth and molars (Diagr. 48) is also approximately the same as in *Sinanthropus*.

Both Adloff (1932) and Dart (1934) emphasize the hominid-like character of the *Australopithecus* dentition. Their conception is based upon the comparison of the *Australopithecus* teeth with those of recent man and those within the Neanderthal group. It receives additional and stronger support by the facts revealed by the dentition of *Sinanthropus*. W. Abel's (1931) conclusion that the peculiarities of the *Australopithecus* dentition must be considered as specializations was made without knowledge of the *Sinanthropus* material. It shows that most of the structural peculiarities, which he considered as specializations, in reality represent primitive hominid characters lost in the course of human evolution. Although Abel ranges *Australopithecus* within the anthropoid group, yet he admits that this ape had never undergone as high a degree of specialization as recent gorilla with its strong development of the canines. Thus, Abel's classification of *Australopithecus* is not too far removed from my own; it diverges only in the judgement of the relationship between *Australopithecus* and the hominids.

The recent discovery of an additional facial fragment of an adult *Australopithecus* briefly described by Broom (1936 a, b) makes evident the hominid-like nature of the dentition of this anthropoid. Dr. Broom very kindly placed a cast of the fragment of the right maxilla at my disposal. The most important fact to be observed is that the upper canine must have been relatively small and the incisors large, the sockets of which only are preserved. If a calculation of the robustness of the upper front teeth of *Australopithecus* on the basis of their outlines of Broom's figure 1 (1936) is correct, then it may be stated that the canine is not much stronger than the central incisor and weaker than the first premolar, In such case *Australopithecus* would approach closer to recent man than *Sinanthropus* who in this respect is nearer to the great apes. Accordingly, there is no diastema between canine and lateral incisors both of which are in contact and thus similar to the condition in hominids. On the other hand, it is remarkable that the premolars and molars, as far as the size and form are concerned—the attrition unfortunately is too advanced to permit judgement of the specific details—reveal a gorilla-like appearance. This is especially true of the relation in size between first and second molar and between premolars and molars, the second molar being much larger than the first one and the premolars relatively stout against the first molar.

E. Schwarz (1936), in a brief note, reviewing Broom's articles (1936 a, b), claims that *Australopithecus* has no hominid character and thus must be considered a pygmy gorilla. Schwarz merely referred to the skull and teeth with no mention of the details of the special features of the dentition of Dart's specimen. As has been demonstrated above, there can be no doubt but that these features resemble much more those of *Sinanthropus*, in other words, of hominids, than any gorilla. I doubt whether the front teeth of Broom's adult specimen can be satisfactorily explained on the basis of a hypothetical pygmy gorilla. Even W. Abel hesitated to define *Australopithecus* as representing a genuine gorilla type. It is certain that *Australopithecus* was not a gorilla and thus does not fall within the range of *Dryopithecus*—recent anthropoids. On the other hand, there is not the slightest doubt that *Australopithecus* does not represent a genuine hominid ("echter Hominide") as was claimed by Adloff (1931). It seems strange that Adloff, who believes that the dentition of anthropoids differs fundamentally from that of hominids, should at the same time consider *Australopithecus* with such numerous ape-like peculiarities as regards brain case, face, mandible and dentition a hominid. The only acceptable reason for classifying *Australopithecus* within the system of higher primates is, as suggested above, that we are dealing with a primate type with a general anthropoid character but at the same time with a surprisingly hominid-like dentition. Such a classification would imply that *Australopithecus* together with hominids belongs to that branch of anthropoids which is characterized by a more homomorphic canine group, in contrast to the other branch represented by *Dryopithecus* and its recent descendants, being provided with a strong hetermorphic canine group. This is in complete accord with Gregory's view contained in a publication quoted by Broom (1937). Gregory, in judging the dentition of *Australopithecus*, states: "If *Australopithecus* is not literally a missing link between the older dryopithecoid group and primitive man, what conceivable combination of ape and human characters would ever be admitted as such?" This viewpoint does not deviate too greatly from that held by Keith (1931) who, considers *Australopithecus* as a "cousin form" of the chimpanzee and gorilla but with an "approach to the human state." In addition he says: "It was certainly more human in its characterization than either gorilla or chimpanzee." Since in the meantime we have gained definite knowledge of the existence of a primitive hominid—*Sinanthropus*—who approaches the gorilla and chimpanzee stock much closer than any other hominid form known hitherto, the relationship of *Australopithecus* to man seems to become also that of a "cousin form".

The literature contains numerous statements as to the primitive character of the human dentition. As has been pointed out repeatedly, the term primitive character in this case implies such peculiarities as characterize recent man in contrast to those of the anthropoids and which consist mainly of a simplicity of the entire tooth pattern. The dentition of *Sinanthropus* incontestably proves that the above understanding is erroneous, and that the simplicity has been secondarily acquired in the course of human evolution. The teeth of genuine primitive hominids are at least as complicated as those of the anthropoids. Thus, if we seek for primitive characters in the hominid dentition, we must take the dentition of *Sinanthropus* as prototype and not that of recent man. The expression primitive in this case would mean nothing else but more generalized and less specialized types when compared with anthropoids. Earlier herein it has been shown that the entire canine group of *Sinanthropus* corresponds to this interpretation. In describing the special pattern of the upper and lower molars attention was drawn to the fact that the configuration of the trigon and trigonid areas in *Sinanthropus,* without crest-like mesial connections between the paracone and the protocone or protoconid and metaconid, has a more primitive appearance than the development of those crests as seen within the group of *Dryopithecus* and descendants. As primitive must be regarded also the peculiar form of the lower canine of *Sinanthropus,* its resemblance to the incisors by having a cutting edge, and its dissimilarity to the upper canine, since similar conditions—at least in principle—may still be found to occur in prosimians of today. Primitive also are the rise of the cingulum to a higher level on the mesial side of the respective teeth than on the distal side, the differentiations of the cingulum and the stylar cusps and the curving of the crown of the lower canine distally. These peculiarities, however, may also occur to a certain extent in anthropoids. Another phenomenon belonging to the same category, though misinterpreted rather frequently, is the reduction of the third upper molar. Its irregularity as well as its smallness in relation to the size of the other molars and its tendency to reduce the distal cusps are not at all peculiarities of the dentition of recent man as commonly assumed, but may be found to occur in the same manner in *Sinanthropus,* in recent anthropoids, in fossil orang, in gibbon, in certain other orders of Catarrhinæ, Platyrrhinæ and in particular in prosimians. This means that we are dealing with a general primate character and, therefore, cannot consider the reduction to be a regressive or even a "degenerative" process characterizing human evolution. It is of interst to note that in Catarrhinæ, with a strongly developed muzzle like the baboons or macaques, the third upper molar exceeds not only the always small first molar in size but even the large second molar. The conditions are quite different with regard to the third lower molar. This tooth in *Sinanthropus* is smaller than the other molars but not at all in the same proportion as the third upper molar. The reduction it has undergone in recent man is stronger than in *Sinanthropus* but in proportion not greater than in other teeth of the lower dentition. Within numerous primate groups—anthropoids, *Dryopithecus* (Gregory and Hellman, 1936) and gorilla (Diagr. 43)—the third lower molar is considerably larger than the second one but not so in orang or chimpanzee (Diagr. 41). As to what extent this may be considered a primitive feature in *Sinanthropus* I do not venture to decide. The fact that in *Sinanthropus,* as in Neanderthal man, the second lower molar erupts before the deciduous dentition is replaced by the permanent one, apparently must be considered as a primitive feature. But this peculiarity *Sinanthropus* also shares with the anthropoids.

The deciduous dentition is of particular interest. The most striking phenomenon is the first molar of *Sinanthropus* which represents, as has been described in detail above (cf. figs. 194, 343 and 344), a really primitive pattern with the entire trigonid and its differentiations preserved. The appearance of this molar thus resembles the conditions of the permanent molars of Eocene Tarsioids. As much as can be judged from the only and rather worn tooth of *Dryopithecus,* this pattern here has already become simplified, a condition which is all the more pronounced in recent anthropoids. The second milk molar of *Sinanthropus* (fig. 202) displays similar primitive structures and the same is true for the canine (figs. 188, 190, 191). In addition, the order of eruption of the milk teeth with the canine appearing as the last tooth must also be taken as a primitive character. Leché (1915) ascertained that the deciduous dentition of all mammals resembles geologically earlier forms with respect to important details to a much higher degree than the permanent dentition. The primitiveness displayed in the case of *Sinanthropus* certainly indicates that it represents, when compared with the *Dryopithecus* group of anthropoids, a less differentiated and, therefore, more primitive stage. The deciduous dentition does not reveal more than that which could already be deduced from the differentiation of the canine group of the permanent dentition, namely that *Sinanthropus* and the hominids retained primary anthropoid characters which were partly lost within the *Dryopithecus* group. The fact that *Australopithecus* also ranges with the hominid group, in regard to its deciduous dentition, has been discussed above.

All these facts combined lead to the same conclusion that hominids and the *Dryopithecus* group represent branches from one and the same special primate stem. This common stem as far as the dentitions are concerned, must, undoubtedly, have been represented by an anthropoid form. For the general appearance as well as the special features of the dentition are such which prevail in present-day anthropoids. There is only one essential exception and that concerns the differentiation of the canine group. The variation of the latter occurring in recent anthropoids, however, proves that the primary conditions are as yet not entirely obliterated. Thus, it may be stated that recent anthropoids retained their original main characteristics, while these have been lost in the course of human evolution. The dentition of recent man represents merely a rather faint copy of its primary nature. Due to this simple fact, attempts to consider in general the human peculiarities deduced from their appearance in recent man as being of primary character and those of anthropoids as secondary acquisitions met with complete failure. Man is a descendant of an anthropoid stock.

Although the nature of the dentition plays an essential part in the judgement of the zoological classification of a given form, yet a correct definition can only be made with the aid of the other parts of the body. As regards *Sinanthropus*, there is no doubt that such parts as are available point to the same direction as the dentition. The new discoveries recently described in preliminary publications (1937 b, c) confirm that *Sinanthropus*, in respect to special form of his brain case, his endocranial conditions and capacity, and the facial skeleton, is a representative of a very primitive hominid type which approaches the suggested anthropoid basic type much closer than any other hominid known hitherto. The maxilla recovered recently and briefly described above (fig. 345) completes the picture. Hence, it is evident that the course of phylogenetic evolution, when traced back from the stage of recent man, gradually leads to an ancestor with an ape-like appearance. Boule (1937) in his valuable contribution to the problem regarding *Sinanthropus* comes to the conclusion, chiefly based on the earlier findings, that *Sinanthropus* must be considered a direct forerunner of recent man but on account of his primitiveness should be distinguished from other hominids, that is to say, Neanderthal mam, and classified as "préhominien." However, Boule himself admits that it is not possible to trace a boundary between "préhominiens" and hominids. Hence, the attribution remains a pure matter of form, and the special labelling of *Sinanthropus* is more or less irrelevant. The essential point of Boule's judgement is acknowledging *Sinanthropus* as representing a direct ancestor of recent man, of a special type and of a much more primitive character than any member of the Neanderthal group. The peculiarities of the *Sinanthropus* dentition fortify this statement against any possible argument.

Not less important than the establishment of the correct position of *Sinanthropus* within the line of evolution is the fact that the variation of the different *Sinanthropus* individuals had already advanced in the direction of Neanderthal and even recent man. I was able to demonstrate this phenomenon in connection with the mandible (1936 b) which, to mention only one of the details, shows typically human mental spines together with a pithecoid-like location of the digastric fossa and the absence of a chin. Such a tendency of the variation has been furthermore confirmed by the discovery of the adult male *Sinanthropus* Skull I, the height and capacity of which considerably exceed the measurements of the other skulls, and finally the dentition described herein has supplied additional evidence in support of the peculiarity in question. Such combinations of progressive and regressive features may be found to occur in one and the same individual as has been shown above. These facts which are not confined to *Sinanthropus* only occasionally may render difficult the correct definition of fossil hominid remains and the judgement of the true nature of a given type. Apparently Davidson Black (1929) had also been deceived by such an unexpected particularity when he stated that there should be a discrepancy between the dentition and the mandible of *Sinanthropus*. He goes on to say: "In adult *Sinanthropus* the architecture of the jaw appears to be much less hominid than that of the teeth which it supports . . . . It can no longer be doubted that distinctive hominid teeth characters were evolved in the human family long before the architecture of the supporting jaw lost its anthropoid form." At the time Davidson Black wrote these sentences (1929) only two mandible fragments and approximately 12 teeth had been recovered. My study on the mandibles as well as this one on the dentition prove that Black's conception of the *Sinanthropus* teeth cannot be maintained. Exactly the reverse condition exists: the general character of the teeth is so primitive that I do not hesitate to proclaim them as being of really anthropoid nature.

VII. THE COURSE OF EVOLUTION WITHIN THE DENTITION AS A WHOLE AND ITS DETERMINING FACTORS

The preceding discussion has made evident that the dentition of the hominids, with *Sinanthropus* occupying the position as the most primitive hominid known hitherto, has undergone a gradual and yet progressive reduction. The size of the crowns and particularly of the roots decreased considerably and produced therewith a characteristic change in the proportions of the teeth. Simultaneously and to the same extent the pattern has become simplified, so that the original highly complicated character of the buccal, lingual and chewing surface have been replaced by those which are surprisingly smooth and plain. The alveolar parts and the entire lower and upper jaws have accordingly become less robust. In consequence thereof the incurvationes mandibulæ and maxillæ anteriores are developed and in connection therewith the chin and the anterior nasal spine are formed. Both the upper and lower jaws have become shortened, and the original dental arcade, narrow and projecting, is replaced by a wide and flat arch.

The transformation of the entire facial skeleton is associated with the development of the brain case but in reverse directions. The brain case tends to enlarge and to seize more and more, so to say, the region occupied by the facial skeleton. The latter loses its dominant position and finally appears as a relatively insignificant appendix to the now dominant brain case. Hence, the reduction and transformation of the dentition is a part of and a correlative reaction in the process of alteration affecting the entire skull. Apparently the enlargement of the brain case, that is to say, the increase in brain size, must be considered as the most conspicuous character of such an alteration. The fact that we are dealing with a correlative process is a further argument against the idea that the simplicity of the teeth of recent man is of original nature.

The literature on human dentition contains a multitude of statements and suppositions in respect to the influence of food upon the structural particularities of teeth. This is easily understood since zoology and palæontology have furnished a great number of evidences to show such a close relationship between the forms of teeth and the nature of food within the entire animal kingdom. Although this fact cannot be doubted, the question remains open as to whether one kind of food or a change of it thereafter may actually and directly cause a corresponding alteration in the character of teeth or whether such adaptations as exist depend upon other factors. I have no intentions of entering into discussion of this extensive problem, but since the alterations in the character of the teeth leading from the *Sinanthropus* phase to that of recent man are so striking, it suggests itself to seek for the fundamental causes of such transformations.

Is it possible that a change of food is capable of producing such complete transformations in the size, shape and pattern of the hominid teeth as suggested by Cope (1889), Gregory (1916) and Dart (1934)? It has been explained that changes within the dentition constitute merely a part in the transformations affecting the entire skull. The jaw, the facial skeleton and the brain case are concurrently transformed. This implies that any change in the character of the dentition is not, in the least, confined to teeth only. Anyone believing that a change of food may produce a specific structural alteration in a tooth must also admit than it is capable of affecting the brain case or of increasing the brain volume. Such a conception is all the more unlikely because it is based upon the assumption that the food has a mechanical effect on teeth.

Moreover, living primates exhibit a great variation in the appearance of their dentition. The pattern of each tooth is so characterisitic for the respective type of primate that one single tooth is sufficient for a correct definition. As far as we know, the same is true for the extinct representatives within this order. Each of the three living anthropoid genera has its specific tooth pattern. But all primates have the same food habits, chiefly composed of fruit, insects, small birds, eggs, shoots, leaves and roots. Thus, it is impossible that the type of food has anything to do, with the special character of the tooth pattern. In contrast to the anthropoids the diet of hominids is largely composed of meat. This is the only change in food habits within the primate order. Can it be a responsible factor for the transformation of the teeth? We do not know the condition of the dentition of the forerunner of *Sinanthropus*, though it may be supposed that the anthropoid character had been more pronounced in the former. Neither are we able to define the time at which hominids changed to a meat diet. We do know, however, that hominids have retained their food habits from the stage of *Sinanthropus* to that of present mankind. The believe held by some people that the chewing of raw or cooked meat requires greater strength in the teeth than the peeling or chewing of fruit and roots, is entirely contradicted by the fact that with the change from the original fruit and root diet to a diet composed largely of meat there has been a decreas in the size and robustness of the human dentition and jaws when compared with anthropoids. Exactly the reverse reaction may be expected. Therefore, there is not the slightest indication that the characteristic transformation of the teeth within the course of evolution of hominids may be explained as being an adaptation to or a consequence of the meat diet.

The possibility of making the cooking of food responsible is likewise remote because the particularities of the dentition characterizing recent man, as different from those of his ancestors, are peculiar to his representatives of all times and places. This understanding implies that they are as peculiar to palæolithic man as to such modern races like the Eskimo who live largely on raw meat or fish. The food habits may influence the attrition but not the size, form or pattern of the teeth.

An excellent example in this respect are the wrinkles and, to a certain degree, also the size, number and arrangement of the cusps. As has been shown in the preceding pages the wrinkles represent a very characteristic feature of the anthropoid dentition, including the hominids. Their general arrangement is the same within all groups but differs in a specific manner within each individual group. On the other hand they cannot be of any functional value, for they disappear almost completely on account of attrition shortly after the eruption of the tooth. For example, in the case of the *Sinanthropus* mandible F 1 (fig. 286) the first molar fails to exhibit any wrinkles, though the second molar is just erupting. Therefore, the wrinkles can scarcely be functioning, if it is permissible to use this term, longer than one half of a year or one year. Notwithstanding this fact they have been found preserved even in recent man occasionally. The same is true to a certain extent in regard to the cusps. Therefore, the belief that the type of food could directly influence the transformation of the teeth and their special patterns does not stand firm against a close scrutiny. Neither can the alterations of the teeth be considered a consequence of chance variations and their subsequent adjustment by selection. If we look through all the variations occurring within the dentition from the stage of *Sinanthropus* up to that of recent man, there is not a single one which could be interpreted as representing a genuine chance variation. All variations exhibit the same major character determined by the tendency of the general course of human evolution, namely to reduce the size of the teeth and to simplify their patterns. It is of considerable significance that, as stated above, even in the stage of *Sinanthropus* teeth with that pattern of advanced development appear in addition to those which still retain their primitive features; and that both types may occur in the same individual. Nothing demonstrates more clearly than this fact of the actual existence of a kind of general "working-plan", if it is allowed to make use of such an ambiguous term. There is no room for chance variations within such a "plan." If variations should really occur, they must be confined to such alterations which are without significance to the course of evolution. The numerous variations occurring in the third lower molar may represent such cases.

On the other hand it is evident that not one of the reported variations is of selective value. This fact cannot be doubted as far as the details of the tooth pattern, such as the wrinkles or cusps or cingulum differentiations, are concerned. Since the wrinkles and cusps constitute rather transient structures, their presence or absence or the special kind of formation cannot be of any value for the purpose of preserving the species. Whether there are 6 or 5 or 4 cusps in the lower molars or whether they are arranged in the *Dryopithecus* or plus pattern certainly is not of great significance in the struggle for life. But the tendency to reduce the number of cusps and to shorten the distal portion of the molars is undoubtedly in line with the general direction taken by evolution, since it merely represents a part of the shortening of the mandible and the entire facial skeleton.

Human evolution, as presented by the dentition, is a typical example of an orthogenetic evolution. The impelling force is contained in the enlargement of the brain. This enlargement apparently stands in direct relation to the upright posture, the adaptation of which must be considered as the most decisive step taken in the evolution of primates leading to man.

VIII. LESIONS WITHIN THE DENTITION

Regarded from the biological point of view, there is no reason to consider the reduction affecting the dentition as a degenerative process. That even the special character of the third molars cannot be placed under this heading has been shown above. The reduction of the entire apparatus of mastication and the structural alterations therein must be taken as mere expressions of specialisation or differentiation which combine to provide for the brain a more dominant place in the body. The same is even true for the appearance of new features conditioned by that process (for example the development of the chin). It is known that many organs in which phylogenetic evolution evolves, decisive alterations are predisposed to injurious affections. The increasing weakening of the crown and roots may explain the reason why the teeth of recent man show such a high degree of decay, whereas the teeth of fossil hominids seem, with a few exceptions, to be immune to it. Both Lenhossek (1919) and Vallois (1934 b) affirmed that indisputable cases of caries could not be ascertained in teeth of any of the representatives within the Neanderthal group. Nevertheless, two doubtful cases are known to exist, one concerns the man of La Chapelle-aux-Saints, the other the Rhodesian man. In the first individual all molars are missing and the alveolar process of the respective parts of the jaw is markedly atrophic. There are, in addition, distinct indications of a purulent process affecting the alveolar process around the roots of the right lower incisors, canine and premolars. Choquet (1912) does not believe that such atrophy and alveolar pyorrhea have to be regarded as the sequel of caries but rather of gout which he described as alveolo-dental polyarthritis. I doubt the correctness of such a diagnosis. The formation of fistulæ resulting from alveolar pyorrhea is not infrequently observed in anthropoids. I have noted certain cases in gorilla and orang skulls which have never been in captivity. The pyorrhea itself may have been a consequence of certain lesions. The adult mandible of Ehringsdorf displays appreciable alterations of the alveolar process which H. Virchow (1920) considers to be due to chronic alveolar pyorrhea. It is also possible that in this case a lesion in the teeth might have caused the changes. In my opinion the loss of the molars in the case of La Chapelle-aux-Saints could be due to caries, for the upper teeth of the Rhodesia man demonstrate the actual occurrence of caries to a devastating extent (Carter, 1928).

As regards *Sinanthropus*, neither teeth nor jaws reveal any pathological changes which may indicate with certainty the occurrence of caries or the existence of alveolar pyorrhea. The illustrations demonstrate that the attrition can reach such extensiveness as to leave the bases of the crowns only. The pulp cavity, however, has not been exposed in any of the cases since the defect in crown is covered by a rather abundant formation of secondary dentine (figs. 127 P^1-M^1 and 142, *o*). The roots also fail to show any pathological conditions. The manner of fusion or better non-division of the branches of the roots, as has been shown above, in no instance deviates from the normal conditions found in anthropoids or recent man. The formation of "prismatic roots" like in the Krapina molars (see above) has not been observed.

The only abnormal phenomenon worthy of note is found in the left, probably first, lower molar No. 38 (fig. 142) and the second upper molar (No. 145′) of *Sinanthropus* maxilla O I. No. 38 represents the small type (female). It was found isolated but most likely belongs to Individual J I, of whom we have a number of isolated teeth (cf. "Dental formulæ"). This lower molar shows a strange indentation on its mesial and distal surfaces (fig. 142, *m*, *d*). The indentations are located just below the lower boundary of the enamel and occupy the greatest part of the neck region. The distal indentation is deeper, narrower and shorter than the mesial one. Its length amounts to 6.8 mm, its breadth to 1.6 mm at the widest part. The indentation which begins on the buccal surface (*b*) but does not reach the lingual border is deepest near the commencement and becomes shallower toward the other end. Its buccal moiety is smooth with its borders slightly elevated, while the area surrounding the lingual moiety is covered by a thin layer of tartar which continues to the neck region of the lingual surface itself. With the aid of a needle this layer of tartar could be easily removed, breaking into fine crystals and thus exposing the underlying dentine. It is interesting to note that the distal contact facet which partly forms the upper border of the indentation is so deep as to cause the enamel to be completely worn off within the entire lower part of the facet, even affecting the dentine. The mesial indentation shows similar conditions. Its length amounts to 7.3 mm, its width to approximately 2.6 mm at its widest, and its depth to approximately 0.5 mm at its deepest. In contrast to the distal indentation, the greatest depth of the mesial one begins on the lingual surface, becoming shallower towards the buccal border without reaching it. The groove itself and the entire surrounding is smooth without traces of tartar. The mesial contact facet shows similar conditions and the same relation to the indentation as the distal one.

The upper molar No. 145′ shows a similar groove of about 1.5 mm breadth and 6.5 mm length which commences on the buccal surface. It does not course horizontally but ascends and then gradually flattens out. The indentation is rather smooth but exhibits a slight deposition of tartar below it. The preserved molar fails to show any depression on its corresponding mesial surface. Similar particularities have not been observed in any of the other *Sinanthropus* teeth. The presence of tartar, however, is not infrequent and it always covers the neck of the molars. It is most pronounced in the first lower molar No. 147′ and in the first upper molar No. 144′ of maxilla O II.

With reference to the interpretation of the indentations, it is significant that H. Martin (1923) described the occurrence of such grooves in the lower molars of the man of La Quina (cf. fig. 215, *a*). In the latter case the grooves occupy exactly the same side and place as in the molars of *Sinanthropus*, and their general appearance is also similar. According to Martin the indentation of the left M_1 is about 1 mm deep and 5 mm long. Both grooves are smooth and there is no indication of tartar or caries. The indentations are found in the first and second molar *in situ* on the surfaces facing each other. H. Martin reports that the same conditions exist in corresponding molars of the right side and within the same mandible. Siffre, a dentist, entrusted to make a special investigation, came to the conclusion (1911) that the indentations in question were lesions caused by the constant usage of toothpicks. He deduced his interpretation from the fact that the grooves occupy the region just above the gum and are located on the two sides opposite each other. In addition, he found that the grooves were deepest from the buccal entrance to the interstitial space and shallower towards the lingual side. Therefore, he is under the impression that such formation could only be caused by the frequent use of a thin and pointed implement to clear the substances lodged between the teeth. Siffre furthermore believes that such a condition had given rise to chronic gingivitis which resulted in the loss of the dentine substance. Martin accepts the interpretation and believes that the meat consumed by the Neanderthal man may have contained sinews, ligaments and aponeuroses and thus caused hard substances to be lodged within the interstices of the teeth. He believes that the toothpick used was in the form of a bone needle.

I doubt the correctness of Siffre's and Martin's interpretations. The idea that Neanderthal man made regular use of toothpicks seems too grotesque to be true. Moreover, I have been unable to find in the literature and indication referring to the occurrence of lesions of the same kind and location as being due to the use of toothpicks among the civilized population of today. In addition, the indentations in *Sinanthropus* show the same location and character as in the case of La Quina. But in one case they are noted to occur on the mesial and distal sides of one tooth and in another case only on one side. Another factor against the hypothesis of the use of toothpicks is that the distal indentation of one lower molar of *Sinanthropus* begins on the buccal surface, while the mesial groove begins on the lingual one. The latter case would imply that the implement had been introduced from the lingual side constantly, a condition which seems rather improbable. Hence, the suggestion that *Sinanthropus* knew the usage of toothpicks seems unfounded.

Before looking for another explanation, it must be determined first whether the indentations are due to postmortem manipulations of the tooth. There are two possibilities, the grooves may either represent marks made by gnawing of rodents or carnivores or by some kind of manipulation by *Sinanthropus* himself. The first possibility seems rather improbable because the location, the alternating direction and the entire character of the grooves do not seem to point towards an interpretation of their being marks made by gnawing. The second possibility that *Sinanthropus* attempted to remove the entire crown of the tooth with a file-like implement or to make an incision for the purpose of fastening the tooth also seems remote. The second alternative would in addition imply that the tooth had been used for ornamental purposes and thus presume the existence of an advanced culture, adequate evidence of which is entirely lacking.

At any rate, I do not believe that such indentations were made after death. For as described above, the lingual moiety of the distal groove of the lower molar and its surrounding is covered by a thin layer of tartar. Any manipulation of the tooth either on the part of animals or *Sinanthropus* would have caused the tartar concretion to break off. The indentations, therefore, must be considered as a pathological condition of the tooth.

The neck of the tooth in recent man is a common seat of the earliest indication of caries. The molars in figure 215 *b* and c represent specimens of recent man obtained from the dental clinic of the Peiping Union Medical College. Within the neck region of the two molars there is an oval pit on the distal or mesial side, respectively, which resembles the indentations observed in *Sinanthropus*. The pits in the teeth of recent man, however, are shorter and relatively deeper, that is to say, more confined in distribution. There is no doubt that these pits were caused by caries. Although I failed to find a case quite analogical to the one of *Sinanthropus* in the limited material at my disposal, and moreover any references to the occurrence in the literature, I believe it possible that these grooves could have resulted from a localized gingivitis. The lower tooth in question is, as has been pointed out in the discussion of the lower molars, not only one of the most squarely shaped lower molars but also is distinguished in particular by the strong abrasion of the tooth substance within the region of the contact facets which extends over the surface and penetrates it. As was noted above, not only the entire enamel is worn off but also the dentine of the crown is affected to a considerable extent (fig. 142, *m, d*). The wear of the contact facet in the case of the upper molar is also rather advanced. Under such conditions an inflammatory process may have developed easily. Since I am not familiar with the various diseases of teeth my interpretation herein is merely a suggestion. It is interesting to note in this connection that, according to Drennan (1929) and Campbell (1925), erosions situated near the gingival margin frequently occur in Australian aboriginals. These erosions are characterized by a wedge- or saucer-shaped shallowness and a dense polished surface. Drennan adds that he found the same feature to a considerable extent in "uncivilized Bushman skulls."

SUMMARY

1. This study is based on 147 *Sinanthropus* teeth derived from the main deposit (Locality I) of Choukoutien. Of these specimens 64 represent isolated teeth, and the remainder of 83 are either embedded within their respective jaws or were found in immediate connection with them or with skulls. 134 specimens belong to the permanent dentition of which 52 are attributed to the upper and 82 to the lower one. 13 specimens pertain to the deciduous dentition and represent lower teeth exclusively. The total number of teeth recovered probably belong to 32 different individuals. The *Sinanthropus* population represented by remains at the end of the spring excavations of 1937 numbers approximately

36 individuals. Of these 20 are of the adolescent or adult age and 12 juveniles ranging from about 4 years to 14 years of age.

2. There are two characteristic types of teeth in the permanent as well as in the deciduous dentition, one being the large type and the other the small one. Since the teeth of the first type were found within the large and robust mandibles G I and K I and together with the large male Skull I Locus L and the teeth of the second type within the small and weak mandibles A II and H I together with the small female Skull II Locus L, it may be stated with certainty that the large type of teeth belongs to male and the small one to female individuals. On the basis of such a definition, 16 represent male individuals and 16 female, that is, 6 male children and 10 male adults and 6 female children and 10 female adults.

3. A comparison of the permanent teeth of *Sinanthropus* with those of either recent man or the Neanderthal group reveals that they are very large and robust in regard to crowns as well as root. The latter at the same time are very high, especially the roots of the front teeth and canines. The crowns of the lower teeth, except the incisors, are longer in relation to the height than is true in other hominid teeth. This peculiarity is most pronounced in the lower premolars and molars. The teeth show a rather stout appearance due to a slight constriction of the roots in the neck region.

4. The teeth are typical on account of the presence of abundant accessory ridges (wrinkles) which represent a constant and characteristic feature. In premolars and molars these ridges are bound to the cusps, the main ridges emerging from the cusps, and to the mesial and distal rim of the chewing surface. Their special feature is characteristic for hominids, their general arrangement being the same as in anthropoids. Accessory ridges of the same nature are also found on the lingual surfaces of the upper and lower canines and the central upper incisor, and in both cases emerge from the basal tubercle. The wrinkles are also present in the deciduous molars.

5. An additional and almost general feature of the *Sinanthropus* teeth is the persistence of the cingulum. It is very pronounced in the two canines and in all premolars and molars. In the latter there are also traces of stylar cusps and in the canine special triangular differentiations on the mesial and distal surfaces.

6. The upper central incisor exhibits a very strongly developed basal tubercle which continues into several finger-like prolongations. The lingual surface is typically shovel-shaped with the border markedly thickened and folded around lingualwards. The tooth is perfectly straight, with the axis of crown and root forming a straight line.

7. In the upper lateral incisor the basal tubercle forms a part of the thickened folded border. The shovel shape is very pronounced, and no prolongations observable. The axis of this tooth also forms a straight line.

8. The lower incisors have a moderately concave lingual surface and a relatively weak basal tubercle. The cutting edge is distinctly crenulated.

9. The upper and lower canines differ in size, robustness and shape. The upper canine is a very large and pointed tooth with a well developed cingulum (see above under 5) and a complicated lingual surface. The lower canine is smaller and less robust; the development of the cingulum is approximately the same as in the upper canine but the configuration of its lingual surface and the tendency to form a cutting edge instead of a tip bear a closer resemblance to incisors than to the upper canine. The resemblance of the canines, especially of the upper one, to the lower canine of the fossil orang of Yünnan is very striking.

10. The first upper premolar is a very strong tooth, its root is divided into two branches or at least shows a deep indentation, in both cases with traces of a third branch. The mesial portion of the basal part of the buccal surface projects considerably, so that the outline of the crown becomes asymmetrical. The buccal cusp is larger and higher than the lingual one, the chewing surface of both cusps exhibiting a characteristic wrinkled pattern.

11. The second upper premolar is weaker than the first one; the main difference of the pattern being that the lingual cusp does not differ appreciably in size and height from the buccal one as is true in the first premolar and that the basal projection is lacking, so that the outline of the crown is completely symmetrical.

12. The first lower premolar in its typical form presents an asymmetrical oblong shape with a well developed cingulum, a distinct talonid and both cusps shifted towards the mesial border of the crown. The metaconid is lower than the protoconid and represents an isolated cusp situated buccally from the thickened lingual rim. The variation in the degree of appearance of the metaconid and of the distinctiveness of the talonid, however, is rather marked. The root is very robust and shows more or less pronounced indications of a division into two or even three branches.

13. The second lower molar in its typical form reveals the same asymmetrical oblong form as the first one. The cingulum is well developed. There is a large talonid covered by wrinkles radiating from the center of the talonid, while the two trigonid cusps are shifted towards the mesial border of the crown. The root is very robust and shows the same tendency as observed in the first premolar, namely to divide into two or three branches.

14. The crowns of the first and second upper molars are quadrangular or rhombic and the four cusps well developed. The paracone projects mesialwards and buccalwards considerably. Cingulum differentiations are very distinct on the buccal surface. There is no clearly discerned trigon pattern, the anterior trigon crest being represented by the mesial rim of the chewing surface and the posterior crest by the slopes of the metacone and protocone themselves. The region of the fovea anterior is a triangular area between these two cusps and the mesial rim. The slope of the metacone covered by wrinkles continues with a separated distal section of the protocone and reaches up to the lingual surface. The root of the first molar is very strong. The lingual branch is straight and diverges considerably. The mesial portion of the buccal branches is much thicker than the lateral portion and is shifted bucally in correspondence to the position of the paracone. The three branches of the root of the second have the tendency to fuse.

15. The third upper molar is smaller than the other molars. The crown is triangular in form with the apex rounded off due to the reduction of the metacone and hypocone. The branches of the root are more or less fused.

16. The Carabelli tubercle appears to be absent in *Sinanthropus*. A Carabelli pit, a special differentiation of the cingulum, was observed in one case. The well developed Carabelli tubercle is a progressive hominid structure and not characteristic of either anthropoids or primitive hominids.

17. The second lower molar is slightly larger than the first one. The crowns of the two molars in their typical form show clear indications of a cingulum and stylar cusps on the buccal surface. The enamel reaches down to a lower level on the buccal than on the lingual surface. The trigonid is broader than the talonid. There are six or five cusps, three of which are situated entirely within the buccal moiety and two or three, respectively, within the lingual one. The metaconid is the largest and longest cusp, the hypoconid occasionally being very small. There is a well developed *Dryopithecus* pattern, with merely a slight tendency to transform it into a plus pattern by reduction of the metaconid. The region of the fovea anterior is represented by a triangular area bordered mesially by the rim of the chewing surface which represents the remainder of the anterior trigonid crest, while the posterior crest is embodied within the slopes of the protoconid and metaconid themselves. The root is very strong with the two branches straight and divergent. The mesial branch is shorter and lower, but thicker than the distal branch and shows a tendency to subdivide the apical part into a buccal and a lingual portion. The branches of the root of the second molar tend to fuse with each other.

18. The third lower molar generally is somewhat smaller than the other molars. Like in the upper molar, the distal cusps, especially the hypoconid and entoconid, are reduced in size. In addition, there is a great variability in the development of all details of the pattern. The branches of the root tend to fuse.

19. The so-called taurodontism as far as it implies a more extensive roominess of the pulp cavity of the teeth, especially of the lower molars, is characteristic for the *Sinanthropus* teeth. It is peculiar to all primitive hominids and may in no case be considered as evidence of specialisation. It may still even occur in recent man (Palæolithic man, Eskimo, Bushman, Amerindians), while on the other hand it may also be found in the chimpanzee and female orang of today. Its disappearance in recent man is a consequence of the reduction in crown size and the alteration of its shape.

20. The deciduous lower teeth of *Sinanthropus* reveal a great number of primitive features. The crowns of the incisors are strong and stout, their roots being relatively robust and high. The incisor has a pyramid-like shape with a distinct point and a well developed cingulum. The first molar is long and narrow with a pronounced cingulum. The tooth is clearly molarized and reveals a complete trigonid with the paraconid, the two trigonid crests and the trigonid pit being preserved. The protoconid is the highest cusp. The talonid is slightly longer than the trigonid but the details of its structure is difficult to recognize because of the advanced degree of attrition. The mesial branch of the root shows an oblique position and projects considerably mesialwards and buccalwards. The second molar is still more molarized. The differentiations of the cingulum are very pronounced. The trigonid with all its characteristic details, namely the paraconid, the crests and the pit are clearly retained and the same is true of the talonid with its basin and the cusps bordering the latter. The root and its branches are very large and stout.

21. It is characteristic for the *Sinanthropus* dentition that a great variability exists with respect to all features of the teeth. Teeth with a very primitive appearance may be found together with rather advanced types, occasionally in one and the same jaw.

22. The permanent teeth cut the gum in the order similar to that known of the teeth of the Neanderthal group, namely the second molar makes its appearance after the eruption of the permanent incisors and before the deciduous canine and molars are shed. In the deciduous dentition the canine is the last erupting tooth as it is the case in anthropoids.

23. With regard to the robustness the permanent teeth may be divided into three groups: the incisor—the canine—and the molar group, the canine group embracing the canine and the two premolars. The incisor group is the weakest, while the molar group is the strongest with the canine group located intermediately. In the lower teeth the difference between the three groups are more pronounced than in the upper teeth in which the incisor and canine groups are stronger in relation to the molars. With respect to these proportions of the three groups *Sinanthropus* bears a much closer resemblance to the gorilla than to the chimpanzee in the upper and lower dentitions of which the incisors are stronger than the premolars and closely approach the molars.

24. The position of the lower incisors within the mandible depends only upon the degree of the angle of inclination which the front part of the mandible forms with the alveolar plane, whereas the teeth themselves do not show any curvature in their longitudinal axis. The same conditions hold good for the upper incisors. The lower and upper jaws exhibit a very pronounced prognathism. To judge from the aspect of the wear facets of the incisors there must have existed overbite relations in the dentition of young individuals with a moderate degree of attrition, while in old individuals with indications of strong wear edge-to-edge bite relations must have been present.

25. The dental arcade represents a relatively narrow curve extending forward, so that the incisors form a more or less equally curved line. A diastema does not exist in either the upper or the lower jaw as far as the permanent dentition is concerned. In the deciduous dentition the lower canine is separated from the lateral incisor as well as from the first molar by a relatively wide gap, the anterior one being broader than the posterior one. The same conditions occur in the deciduous dentition of the anthropoids.

26. The upper permanent canine is not only larger and stouter than the lower one but it also projects considerably beyond the general level of the chewing surface, exceeding particularly the height of the crown of the first upper premolar.

27. When compared with *Sinanthropus* the teeth of recent man have undergone a very characteristic reduction. This reduction involves not only the size of the crowns and the roots (see under 3) but apparently also a specific transformation of the entire pattern and in certain tooth types even an alteration of the entire shape. The cingulum and the wrinkles have been more or less lost and all teeth appear to be much simpler and their surfaces smoother. The crowns of the lower premolars have become completely symmetrical due to the shortening of the talonid. In the lower molars this process resulted in the adaptation of a more square form with the cusps, especially the metaconid, decreased in size, their number diminished (four instead of six) and their arrangement altered (plus pattern instead of *Dryopithecus* pattern). The lower canine has lost its cutting edge and by acquiring a tip has taken on the appearance of the upper canine which makes them practically identical. The third upper molar is involved in this process of reduction only as far as the finer details of the pattern are concerned. But the decrease in size of the crown and its distal cusps including the root did not advance any further. In this regard the third molar of the hominids displays the same conditions as exist in other primate groups with not too elongated muzzles. The third lower molar shows the same degree of reduction as the other but not to such an excess.

28. The teeth of the Neanderthal group approach much closer those of recent man than those of *Sinanthropus*, the reduction in that group having already advanced to a considerable extent. Only traces of the cingulum differentiations, the persistence of the wrinkles and certain other details indicate the intermediary position of the teeth of Neanderthal man (between *Sinanthropus* and recent man). There is not the slightest doubt that *Sinanthropus*, as far as the teeth are concerned, represents a much more primitive hominid type than any member of the Neanderthal group. A great variability may also be observed within this group. The teeth of the Heidelberg mandible, for instance, do not differ to any appreciable degree from those of recent man, despite their geological age. The Taubach molar with all its peculiarities also falls completely within the range of variation of the Neanderthal group.

29. All characteristics of the *Sinanthropus* teeth reveal their closest relation to the anthropoids. The frequently voiced opinion that the hominid teeth have nothing in common with those of the latter was erroneously based upon the idea that the simplicity displayed by recent human teeth represents an original appearance, and, therefore, must be considered as specific for actually primitive primates. The real facts fully retract any such conception.

30. The *Sinanthropus* teeth as a whole resemble those of lower and primitive extinct or recent primates only as far as the rather general characteristics of primate teeth are concerned. But in all special features such as the differentiations, the wrinkles, the size, number and arrangement of the cusps, the feature of the roots and their branches the *Sinanthropus* teeth conform in principle to those of the anthropoids and differ, together with the latter group, from the teeth of all other primate groups. When applying the teeth as criterion for the classification, there is no other choice but to range *Sinanthropus* within the general group of anthropoids.

31. The only difference of some importance is the special form of the canines and the first lower premolar. Although the canine of *Sinanthropus* has already undergone a reduction, yet it cannot be surmised that it had at any time been such a tusk-like structure as is true in anthropoids; the premolar likewise probably never had such a sectorial character as that found in anthropoids. These teeth apparently were the center of special differentiations in anthropoids which were already effective in *Dryopithecus*. Hence, the hominids must have branched off from the common stem of the anthropoid stock before *Dryopithecus* and the other fossil member of this group developed. The stem was thus divided into two branches, one with a more homomorphic canine group leading to or represented

by the hominids, and the other with a heteromorphic canine group leading to *Dryopithecus*, its relatives and its descendants, that is to say, to the anthropoids in the strict sense of the term.

32. General primitive primate characters retained in the teeth of *Sinanthropus* consist of the persistence of the trigonid in the two deciduous molars and probably also of the incisor-like appearance of the lower canine and the greater homogeneity of the entire canine group. But the number of these archaic peculiarities is rather small when compared with all the other features which *Sinanthropus* has in common with the anthropoids. It must be borne in mind, however, that in the fossil orang and even in the chimpanzee of today such primitive structures may be found to occur as individual variations, thus pointing to a common anthropoid origin.

33. Of all fossil anthropoid-like primates know hitherto *Australopithecus* bears the closest resemblance to *Sinanthropus* with regard to the dentition. This is true not only of the first permanent molars but also of the deciduous molars and the proportion of the size of the incisors in relation to the molars. The lack of a diastema and the remarkable smallness of the canine in Broom's *Australopithecus* point in the same direction. Therefore, *Australopithecus* apparently belongs to the same anthropoid main branch as the hominids characterized by the greater homogeneity of the canine group (see under 31).

34. The so-called *Pithecanthropus* teeth attributed as belonging to the skull cap cannot have any relation to the latter if *Sinanthropus* is taken as prototype of a primitive hominid, and the skull of the former considered as closely related to that of *Sinanthropus*, and less so if the skull cap is taken to belong to a giant gibbon as is assumed by Dubois. The lower premolar in its entire appearance is like that of recent man, while the upper molars show all characteristics of orang teeth. That orang had existed contemporaneously with *Pithecanthropus* has been confirmed by recent finds. In addition, the differences in size between the premolar and the molars are so great that the three teeth could never have belonged to the same dentition.

35. The teeth of the Piltdown remains are of three different origins. The two molars embedded within the mandible are typical anthropoid teeth, revealing such peculiarities as are found in the orang of today. These teeth, therefore, correspond entirely in their morphological character to the mandible with its orang-like appearance. The left molar recovered as an isolated tooth represents a type of recent man. As to the "canine' it is certain that it does not represent a lower canine of an anthropoid. Its real nature remains to be determined.

36. The reduction of the hominid dentition in the course of evolution as demonstrated by the three phases; *Sinanthropus*—Neanderthal man—recent man—cannot be considered an isolated process confined to the teeth but a consequence of the transformation of the entire skull. The reduction in size of the lower front teeth including the canine, particularly in that of their roots, leads to a reduction of the alveolar process and as a consequence thereof to the projection of the basal part of the mandible, resulting in the formation of a chin. In the upper teeth a similar transformation took place. The reduction of the alveolar process here led to the development of the nasal spine and to a characteristic alteration of the entire appearance of the maxilla which may be called "hollow cheeks." The reduction of the entire masticatory apparatus is closely connected with the enlargement of the brain and its expansion at the expense of the facial parts of the skull.

37. Everything that occurs in the dentition is only a consequence of a general transformation and cannot be the result of any accidental and direct influence upon teeth such as a change in nutrition, nor of a selection of unlimited chance variations. Neither can the different structures peculiar to hominids or other members of the anthropoid groups be caused by differences in the nutrition. They are particularities genuinely adherent to their special type like all other characteristics of the body.

38. The course of human evolution as much a is manifest in the dentition is a typical example of an orthogenetic evolution involving the entire organization and influencing every individual system of the body towards a

development in the same direction. Neither this process as a whole nor the accompanying alterations may be considered as degenerations. They represent a distinct specialization in which the brain seems to have assumed the leading part.

39. *Sinanthropus* must be considered as a stage leading directly to recent man (see also under 27 and 28). The teeth show no features whatever which could be taken as "specializations." The very pronounced shovel shape pattern of the upper central and lateral incisors, particularly the latter (see under 6 and 7) is found to occur also in certain Mongol types of present mankind and thereby proves—with other peculiarities of the skull and mandible—the close relationship of *Sinanthropus* to that racial group.

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PALÆONTOLOGIA SINICA

THE DENTITION OF *SINANTHROPUS PEKINENSIS:*
A COMPARATIVE ODONTOGRAPHY OF THE HOMINIDS

BY

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Visiting Professor of Anatomy, Peiping Union Medical College

Atlas with Plates I-XXXVI and 49 Diagrams

古生物誌

地質調查所

Peiping, 1937

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NOTE: Unless otherwise indicated, all illustrations are × 2 *natural size.*

REMARKS ON ABBREVIATIONS

The number following the types refers to the current catalogue number of the *Sinanthropus* specimens and listed under the sub-title "Material" in the main text. By referring to the number all essential details concerning the tooth will be found, together with data on the relationship of the tooth to the jaw and other teeth of the respective dentition. In addition, the latter is represented in the form of dental formulae which are given on a separate list appended to the same section.

Italicized numbers refer to teeth embedded within the jaws or found in connection with the pertaining jaws or skulls.

For an explanation of the letters designating the tooth type the reader is referred to the part entitled "Designations and Methods" in the text.

Abbreviations:-
b = buccal view
d = distal view or distal side
l = lingual view
lt = left side
m = mesial view or mesial side
o = occlusal view
p = 3/4 profile view
rt = right side

EXPLANATION OF

PLATE I

1

PLATE I

Figure 1. *Sinanthropus* 4. I^1 lt; b, l, m, d, o.

Figure 2. *Sinanthropus* 3. I^1 lt; b, l, m, d.

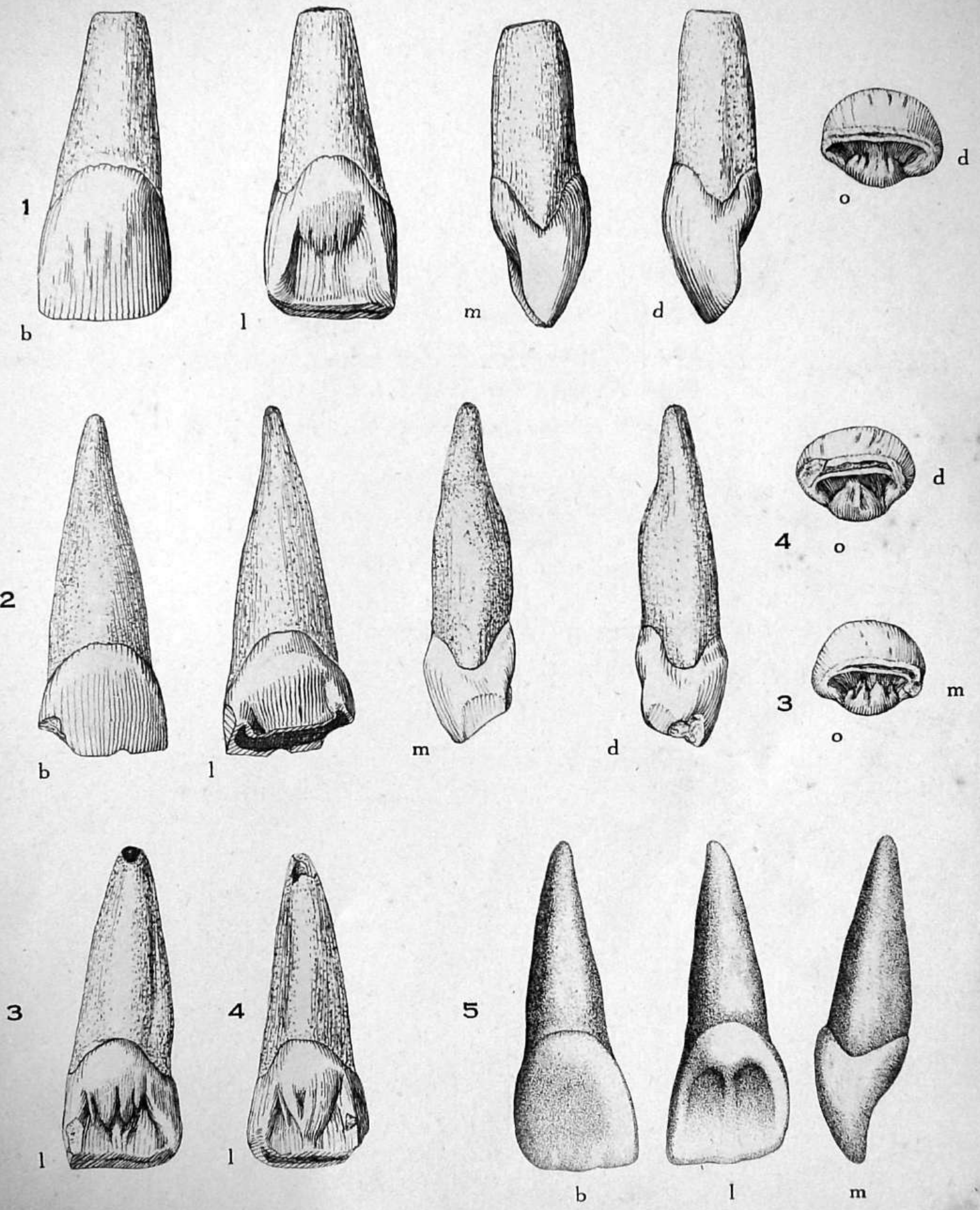
Figure 3. *Sinanthropus* 2. I^1 rt; l, o.

Figure 4. *Sinanthropus* 1. I^1 lt; l, o.

Figure 5. Recent Man (Lenhossek). . I^1 rt; b, l, m.

Weidenreich—Sinanthropus teeth

Plate I, figs. 1-5



EXPLANATION OF

PLATE II

PLATE II

Figure 6. Ehringsdorf child I^1 lt. From photographs and casts.

Figure 7. Krapina I^1 rt after Gorjanovic-Kramberger.

Figure 8. Le Moustier I^1 rt. From photographs.

Figure 9. Choukoutien "Upper Cave" I^1 rt (Cat. No. 159).

Figure 10. Recent Australian Aboriginal (Cat. No. 688) I^1 and I^2 lt.

Figure 11. Recent North Chinese ♂ (Cat. No. 191). I^1 rt and lt; I^2 rt and lt.

Figure 12. Recent North Chinese ♂ (Cat. No. 132). I^1 rt.

Figure 13. Recent North Chinese ♂ (Cat. No. 91). I^1 lt.

Figure 14. Chimpanzee juv. ♂ (Cat. No. 426). I^1 rt and I^2 rt; 1/1.

Figure 15. Gorilla juv. ♀ (Cat. No. 392). I^1 rt and lt; 1/1.

Figure 16. Chimpanzee juv. (Cat. No. 390) I^1 lt.

Figure 17. Orang juv. ♂ (Cat. No. 20). I^1 rt and lt. 1/1.

Figure 18. *Sinanthropus* 7. I^2 rt; b, l, m, d.

Figure 19. *Sinanthropus* 6. I^2 rt; l, o.

Weidenreich—Sinanthropus teeth

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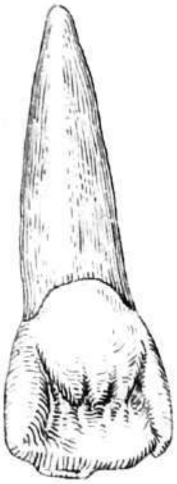

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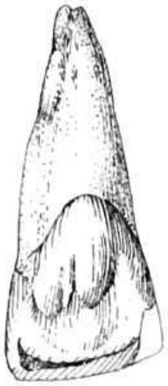

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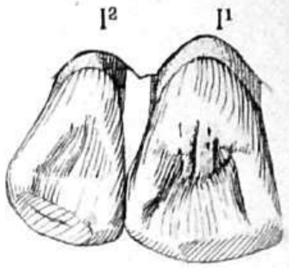

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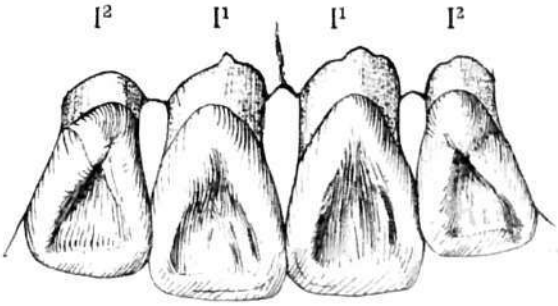

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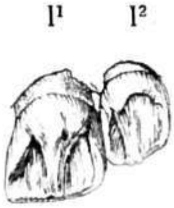

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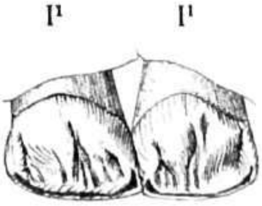

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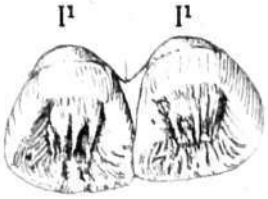

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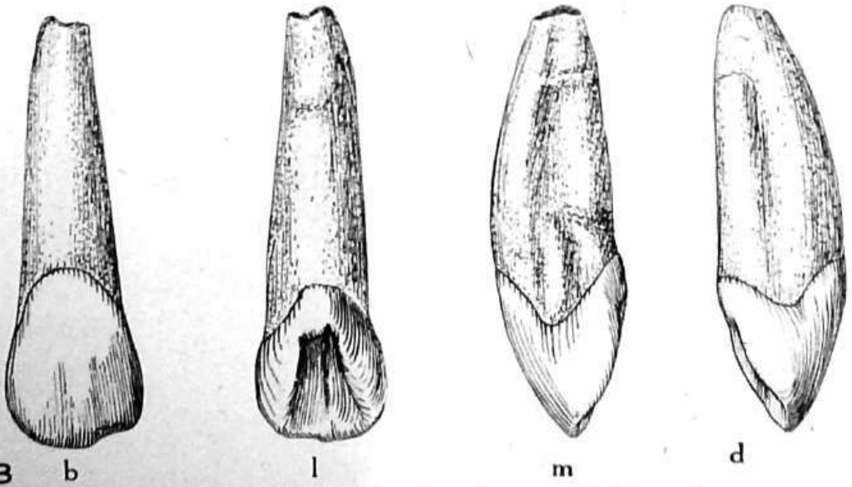

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EXPLANATION OF

PLATE III

PLATE III

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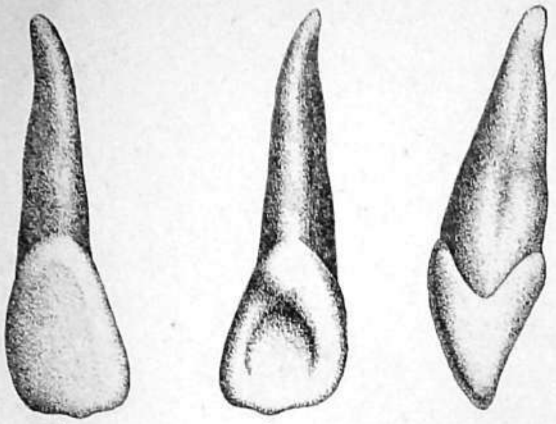
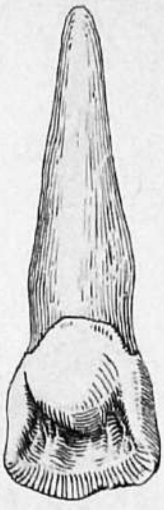
Figure 32. Recent Man (Lenhossek). I_1 rt; b, l, m.
Figure 33. *Sinanthropus* 8. I_2 lt; b, l, m, d.



20 b l m



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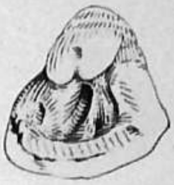

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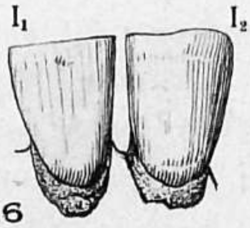

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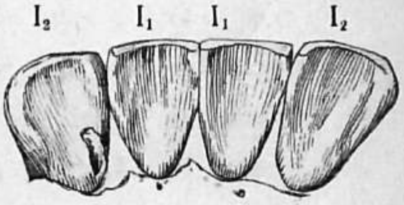

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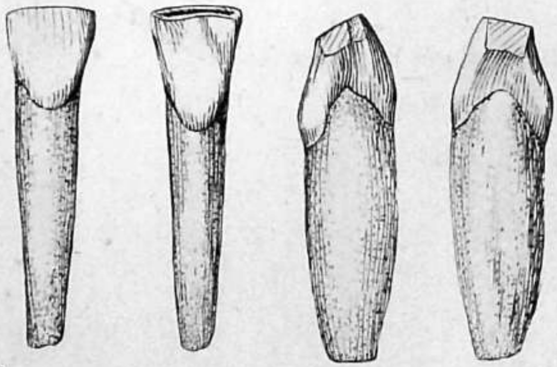

28 b l m d

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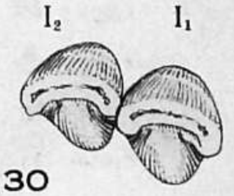

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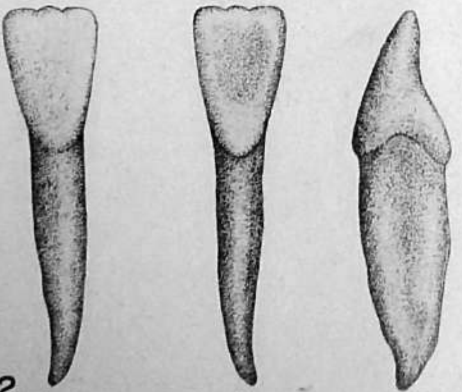
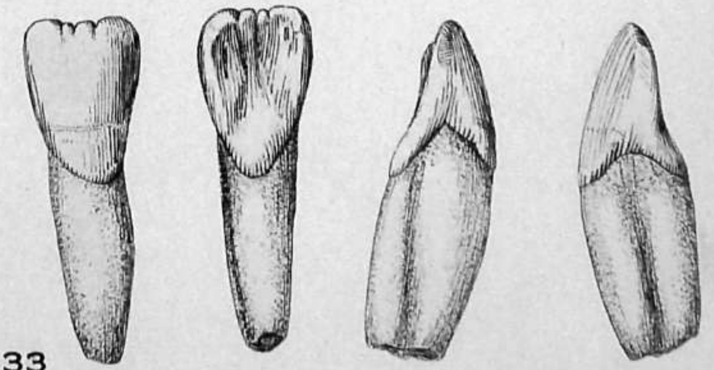


32 b l m



33 b l m d

EXPLANATION OF

PLATE IV

PLATE IV

Figure 34. *Sinanthropus* 10. I_2 rt; b, l, m, d.

Figure 35. Recent man (Lenhossek). I_2 rt; b, l, m.

Figure 36. *Sinanthropus* 11. I_2 lt; b, l, m, d.

Figure 37. *Sinanthropus* 12. I_2 rt; b, l, m, d.

Figure 38. *Sinanthropus* 16. C′ rt; b, l, m, d, o.

Figure 39. *Sinanthropus* 13. C′ lt; b, l, m, d, o.

Figure 40. Le Moustier C′ rt, l. From photographs.

Figure 41. Krapina C′ rt; b; after Gorjanovic-Kramberger. Size?

Weidenreich—Sinanthropus teeth

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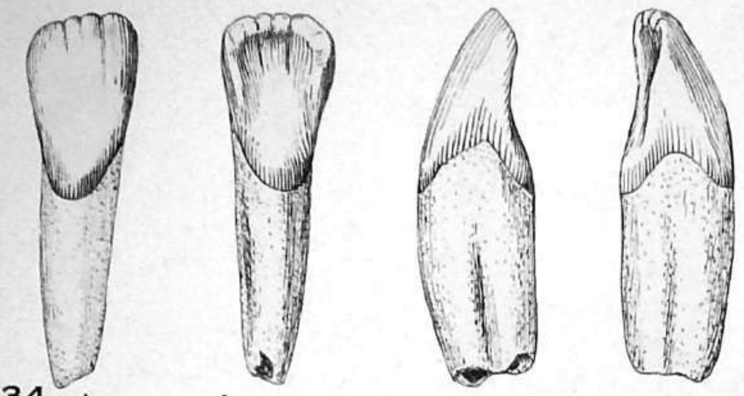

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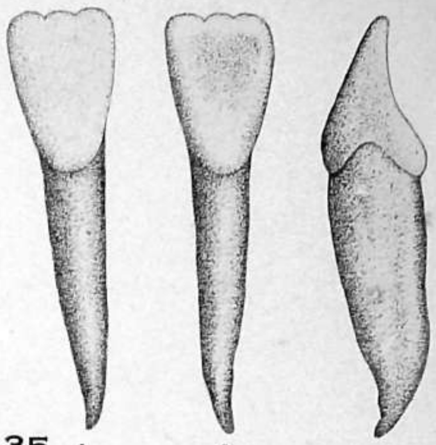

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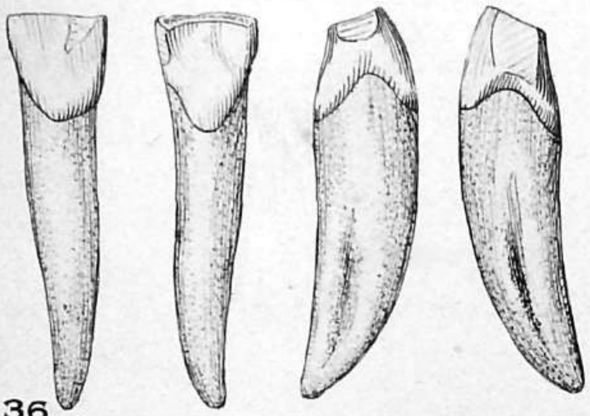

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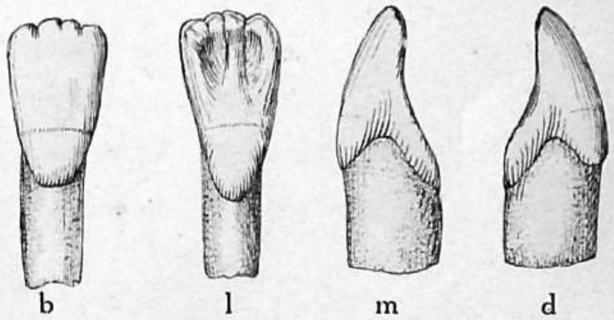

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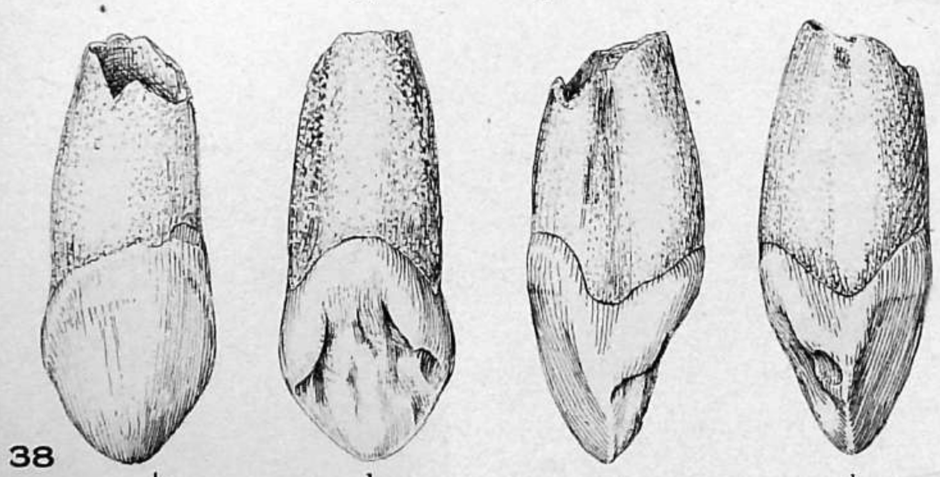

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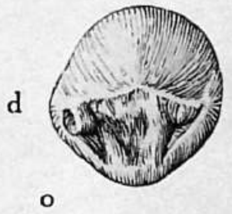

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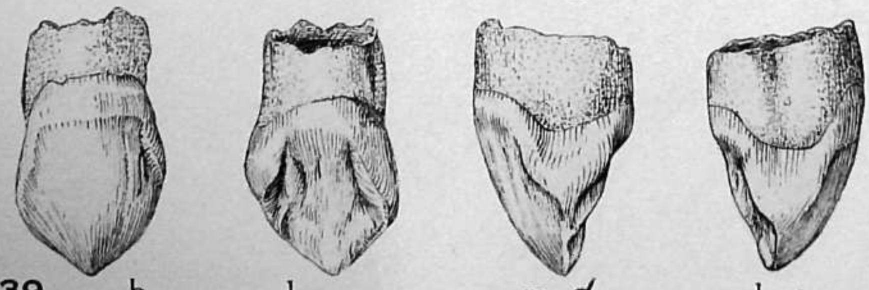

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EXPLANATION OF

PLATE V

PLATE V

Figure 42. *Sinanthropus* 14. C′ rt; b, l, m, d, o.

Figure 43. *Sinanthropus* 15. C′ lt; b, l, m, d, o.

Figure 44. Recent Man (Lenhossek). C′ rt; b, l, m.

Figure 45. Recent Australian Aboriginal ♂ (Cat. No. 14). C′ rt; l.

Figure 46. Recent North Chinese ♂ (Cat. No. 191). C′ lt.

Figure 47. Recent North Chinese ♂ (Cat. No. 174), C′ lt.

Figure 48. Recent North Chinese ♀ (Cat. No. 96). C′ lt.

Figure 49. Recent North Chinese ♂ (Cat. No. 181). C′ lt and I^2 lt.

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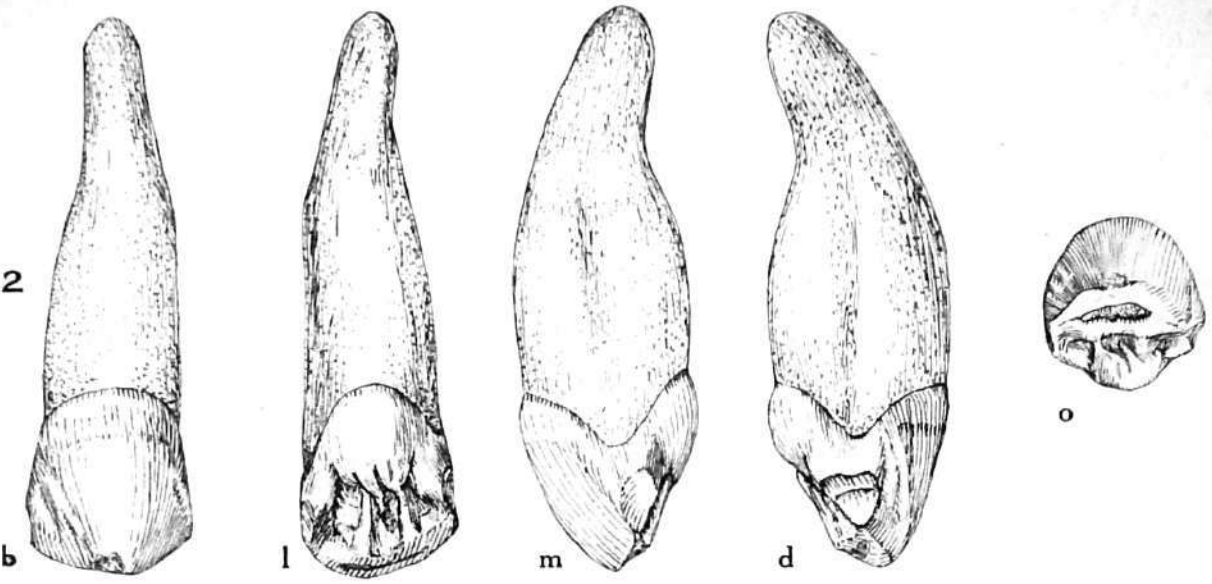

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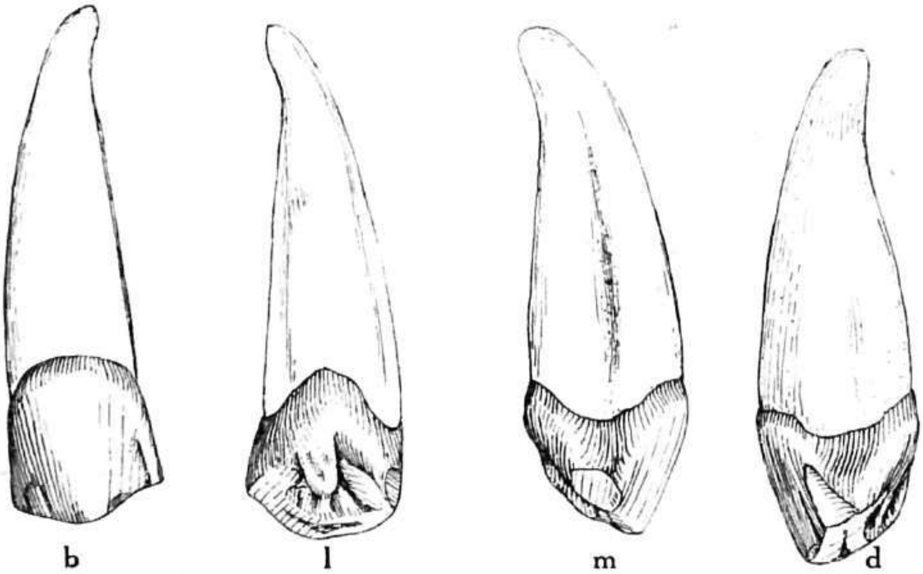

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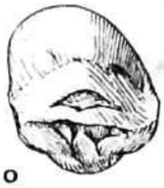

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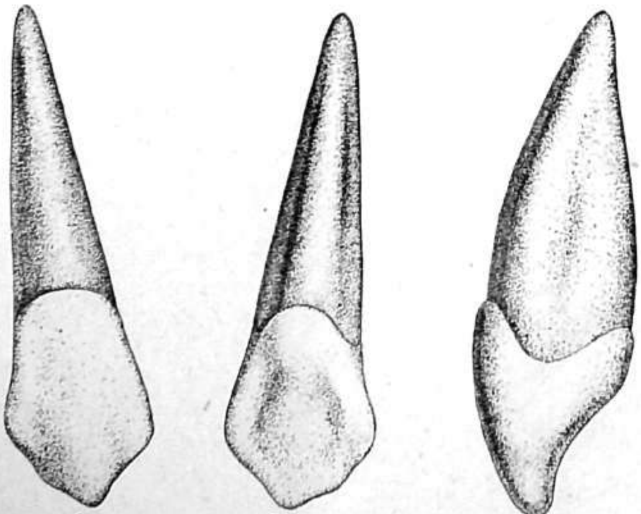

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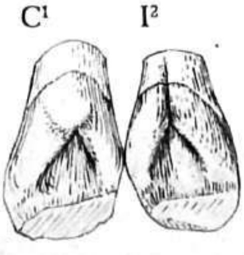


EXPLANATION OF

PLATE VI

PLATE VI

Figure 50. *Sinanthropus 70.* C, lt; b, l, m, d, o.

Figure 51. *Sinanthropus 71.* C, rt; b, l.

Figure 52. *Sinanthropus 72.* C, lt; b, l, d.

Figure 53. *Sinanthropus* 18. C, lt; b, l, m.

Figure 54. *Sinanthropus* (jaw G I). *73* C, lt; *83* P_1 lt; *91* P_2 lt; b.

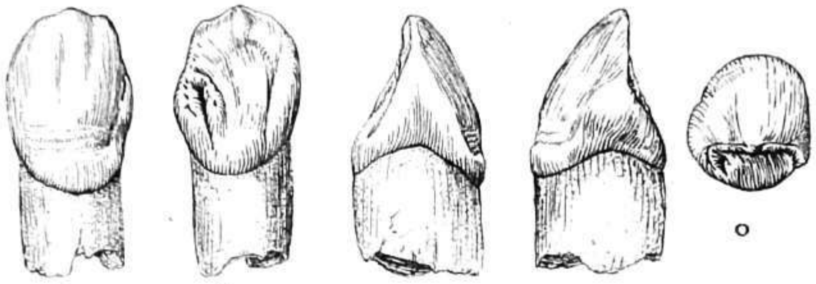
Figure 55. *Sinanthropus 75.* C, lt; b, l, m, d.

Figure 56. *Sinanthropus 73.* C, lt; l (cf. fig. 54).

Figure 57. Ehringsdorf C, rt; b, l. From photographs.

Figure 58. Krapina C, lt; l. After Gorjanovic-Kramberger.

Figure 59. Recent Chinese (prehistoric Mongol, Cat. No. 157). C, rt, b.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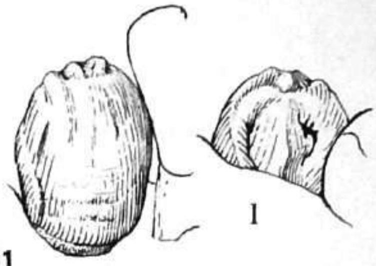
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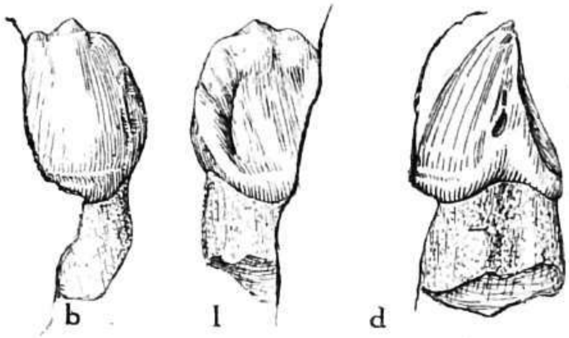
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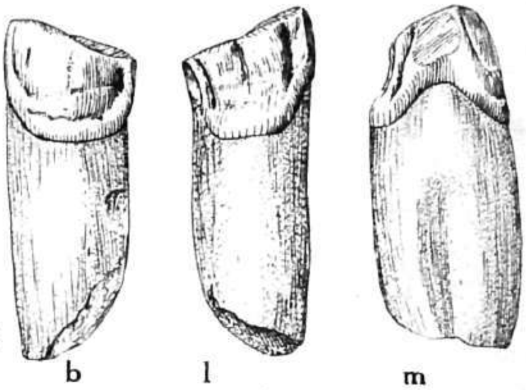
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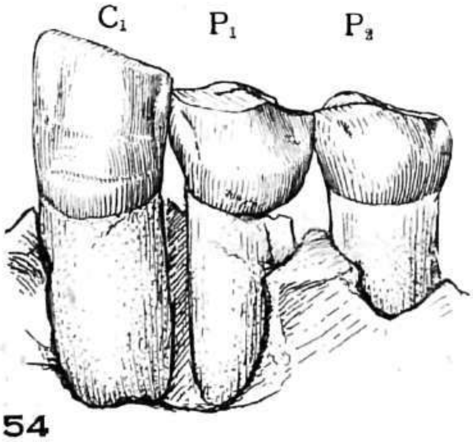
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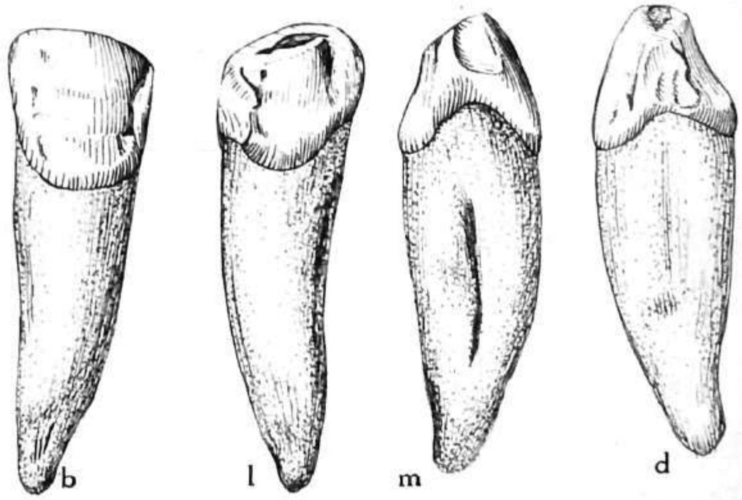
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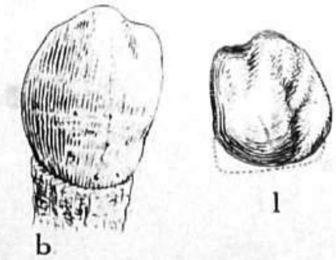
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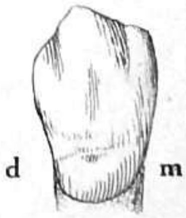
59

EXPLANATION OF

PLATE VII

PLATE VII

Figure 60. *Sinanthropus* 17. C, lt; b, l, m, d, o.

Figure 61. Fossil orang (Yünnan) ♀. C, rt; b, l, m, d, o.

Figure 62. Omitted because of error in designation.

Figure 63. Recent Man (Lenhossek). C, rt; b, l, m.

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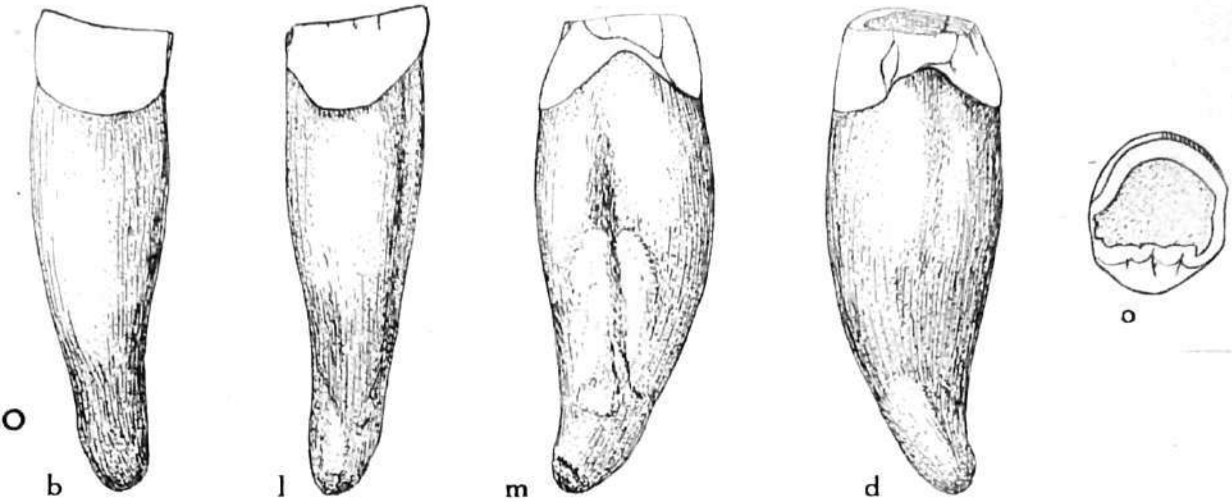

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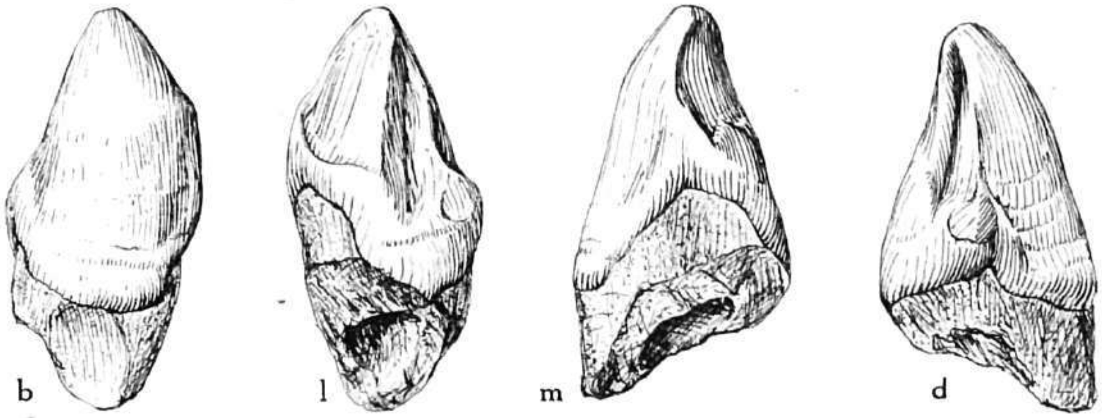

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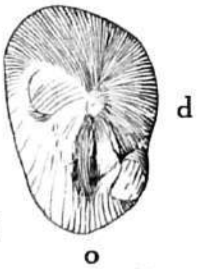

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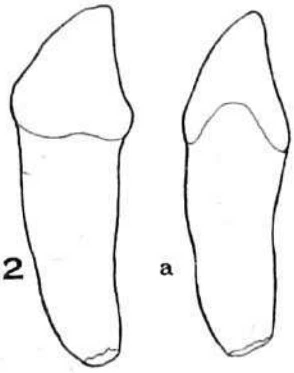

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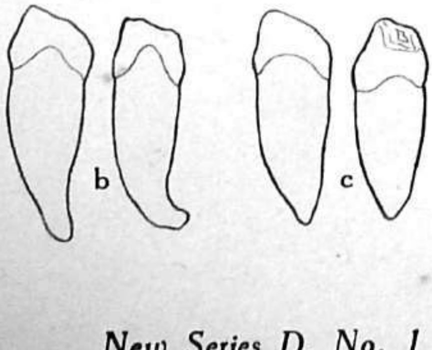

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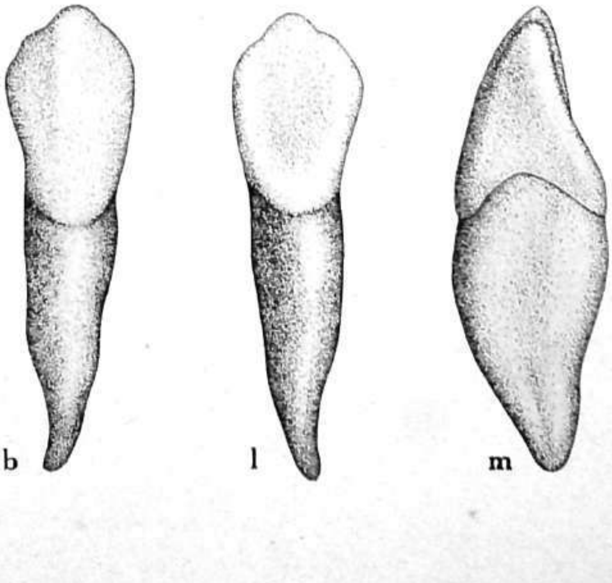

EXPLANATION OF
PLATE VIII

PLATE VIII

Figure 64. *Sinanthropus* 19. P^1 rt; b, l, m, d, o.

Figure 65. *Sinanthropus* 77. P^1 lt; b, l, d, o (m compare with fig. 73).

Figure 66. Prehistoric Chinese (Kansu, Cat. No. 400/23). C, lt and P_1 lt (b), with strong attrition.

Figure 67. Recent North Chinese (Cat. No. 69). C, lt and P_1 lt (b) with slight attrition.

Figure 68. *Sinanthropus 78.* P^1 rt, b, l, m (d compare fig. 73).

Figure 69. Recent Man (Lenhossek). P^1 rt; b, l, m.

Figure 70. Le Moustier P^1 lt; o. From photographs.

Figure 71. Krapina P^1 rt, o. After Gorjanovic Kramberger. Size?

Figure 72. Recent Australian Aboriginal (Cat. No. 14). P^1 rt, o; no attrition.

Weidenreich—Sinanthropus teeth Plate VIII, figs. 64-72

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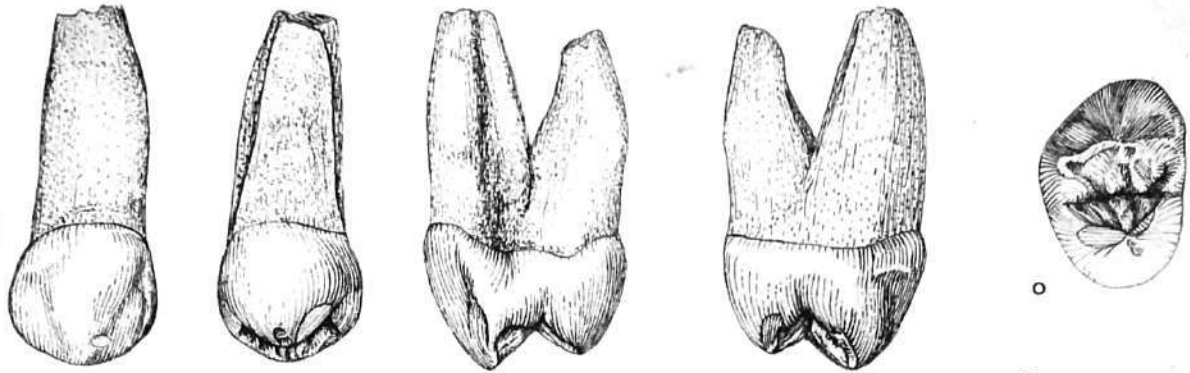

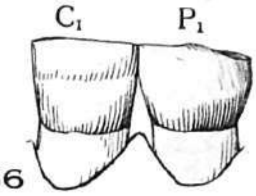

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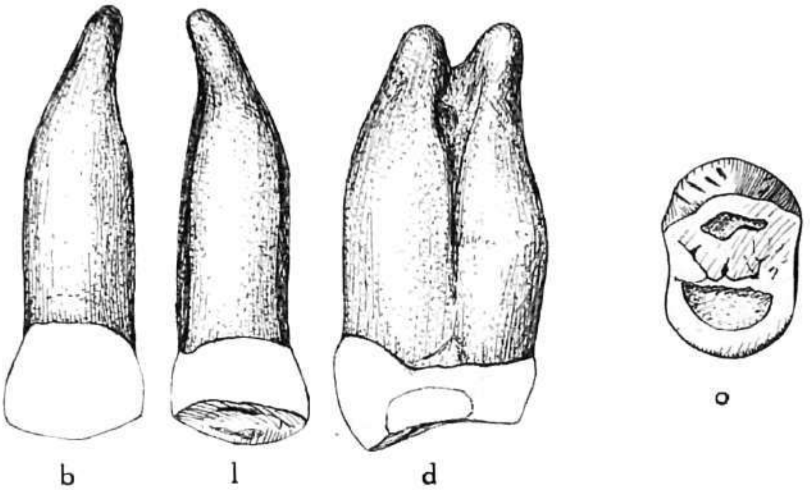

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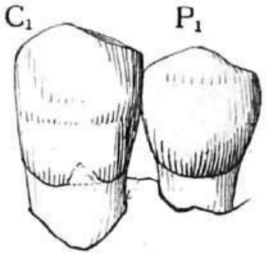

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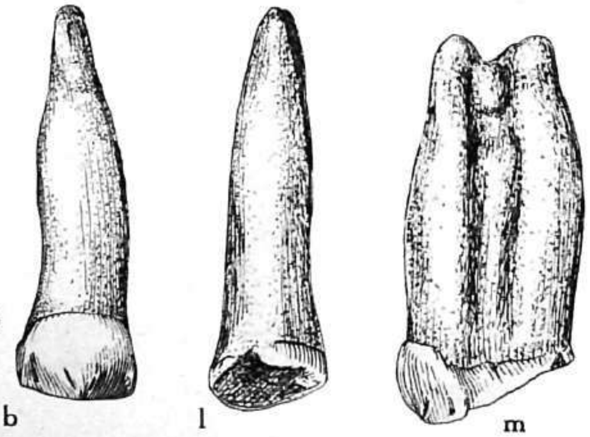

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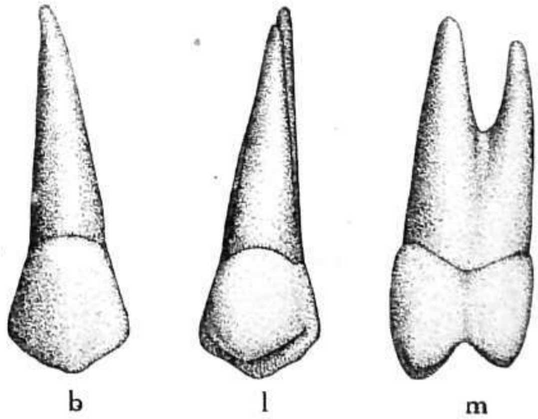

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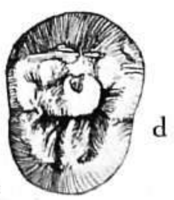

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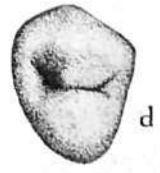


69 o

EXPLANATION OF

PLATE IX

PLATE IX

Figure 73. Comparative lateral views of C' and P^1 of *Sinanthropus* to demonstrate the difference in size between the large (♂) type (♂ Skull I Loc. L) and the small (♀) type (♀ Skull II Loc. L): a) *68* C' rt d; b) *69* C' lt m; c) *77* P^1 lt m; d) *78* P^1 rt d.

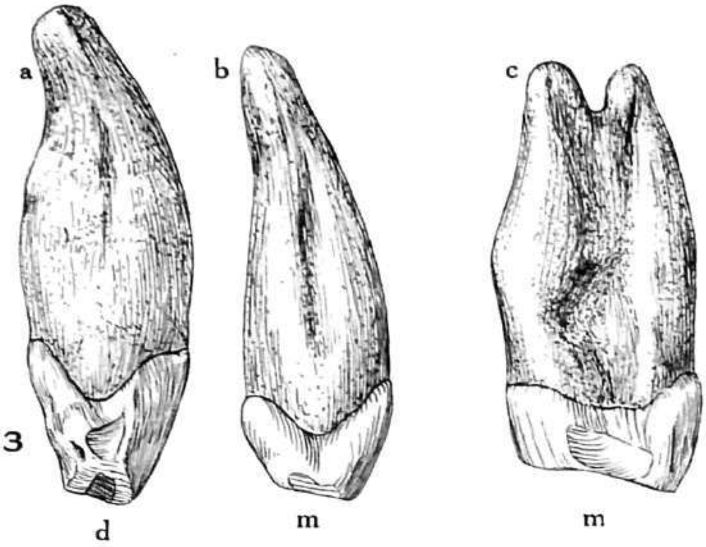
Figure 74. Le Moustier P^2 lt. From photographs. circa 3/1.

Figure 75. *Sinanthropus 87*. P^2 rt; b, l, m, d.

Figure 76. Recent Man (Lenhossek). P^2 rt; b, l, m, o.

Figure 77. *Sinanthropus* 25. P^3 lt; b, l, m, d, o.

Figure 78. *Sinanthropus* 27. P^2 lt; b, l, m, d, o.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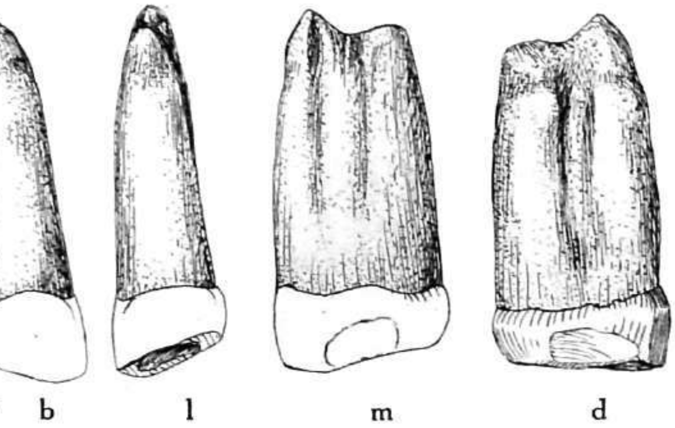
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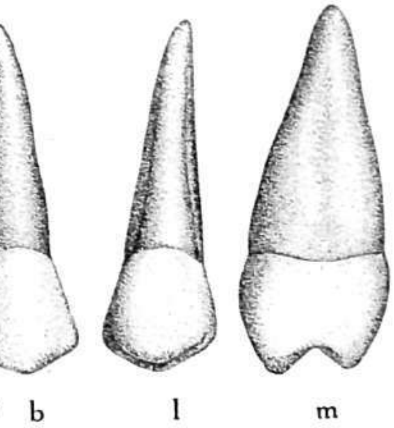
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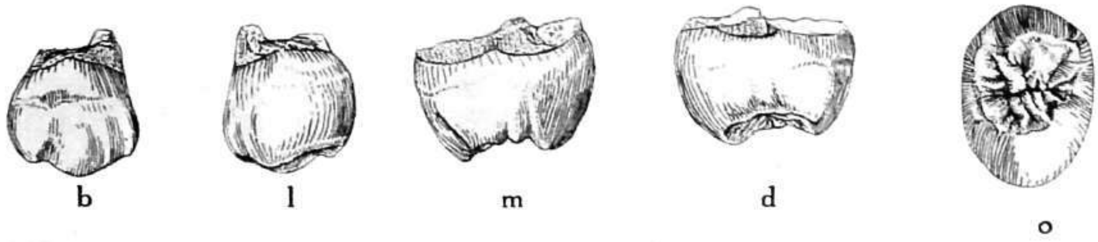
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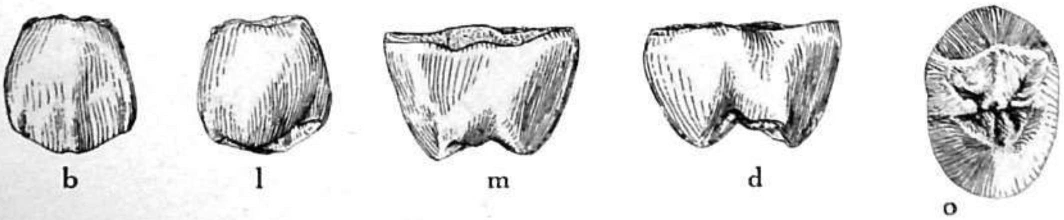
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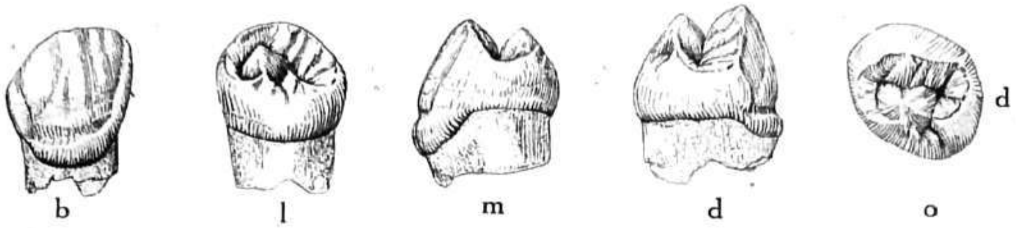
EXPLANATION OF

PLATE X

PLATE X

Figure 79. *Sinanthropus 80.* P_1 rt; b, l, m, d, o.
Figure 80. *Sinanthropus* 20. P_1 rt; b, l, m, d, o.
Figure 81. Chimpanzee ♂ adult; P_1 rt; b, l, m, d, o.
Figure 82. *Sinanthropus 82.* P_1 rt; b, l, m, d, o. (compare fig. 91).
Figure 83. *Sinanthropus 81.* P_1 rt; b, l, o.
Figure 84. *Sinanthropus* (Zdansky). P_1 lt; o.
Figure 85. Recent Man (Lenhossek). P_1 rt; b, l, m, o.

79



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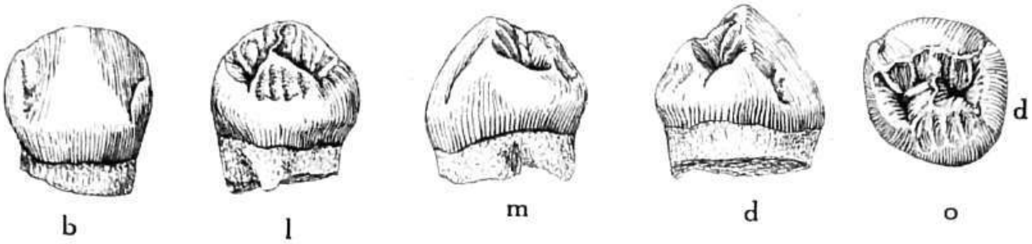

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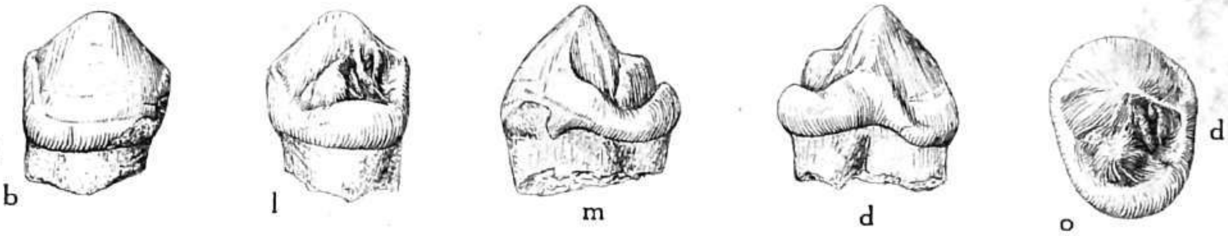

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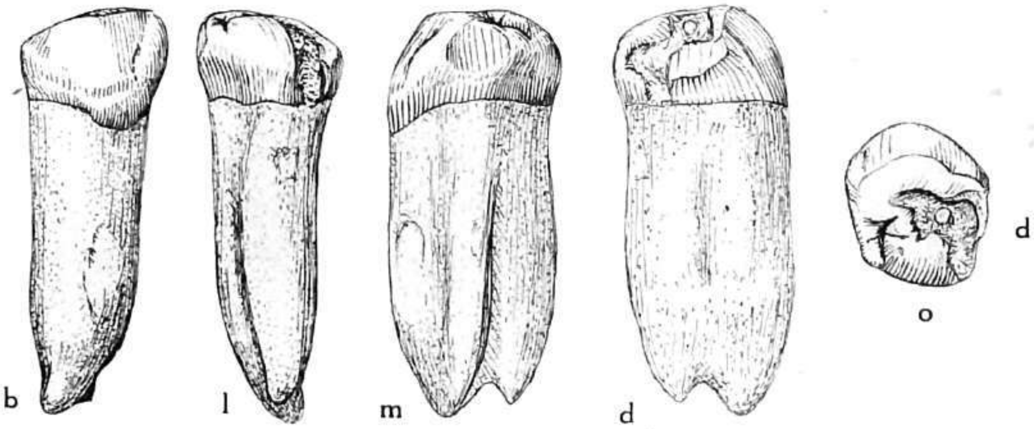

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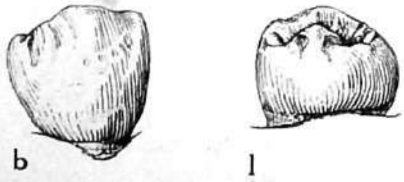

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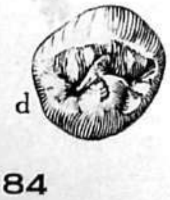

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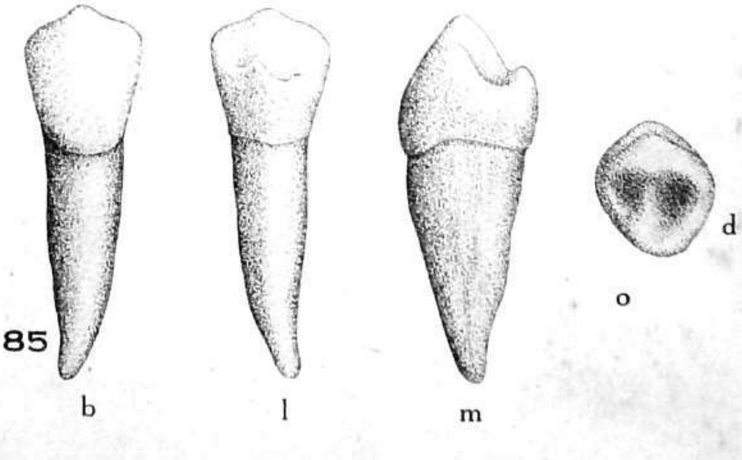


EXPLANATION OF
PLATE XI

PLATE XI

Figure 86. *Sinanthropus 85.* P_1 lt; b, l, m, d, o.

Figure 87. *Sinanthropus* 21. P_1 rt; b, l, m, d, o.

Figure 88. Fossil orang (Kwangsi). P_1 rt viewed from buccal side and from below.

Figure 89. *Sinanthropus* 23. P_1 rt; b, l, d.

Figure 90. Chimpanzee juv. ♂ (Cat. No. 426). P_1 and P_2 with partly fused roots: a) P_1 lt, m; b) P_2 lt, m; c) P_2 rt, b.

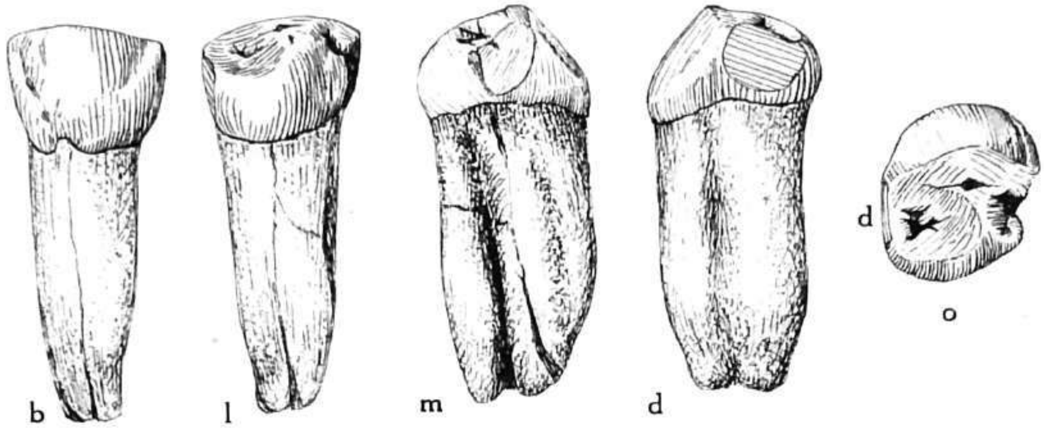
Figure 91. *Sinanthropus 82.* P_1 rt (compare fig. 82), to demonstrate the fused root viewed from the apex and the distal and buccal sides.

Figure 92. Ehringsdorf child P_1 rt; b, o, from photographs.

Figure 93. Krapina P_1 rt; o, after Gorjanovic-Kramberger. Size ?

Figure 94. Le Moustier P_1 rt; o, from photographs and after H. Virchow.

Figure 95. Heidelberg P_1 rt; o, after Schoetensack.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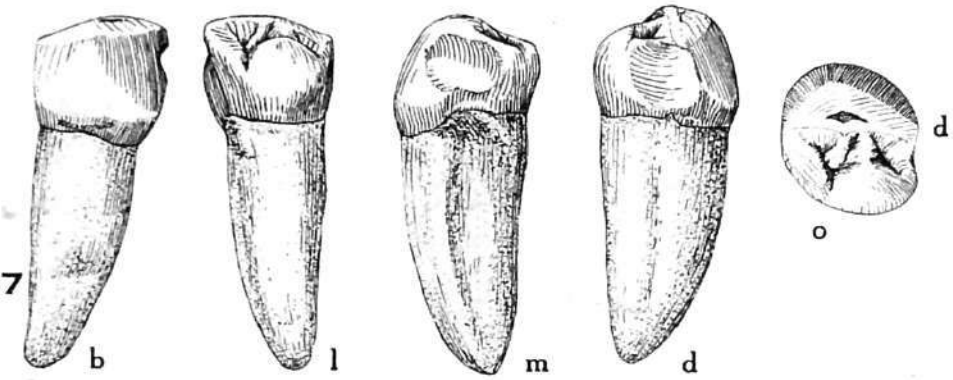
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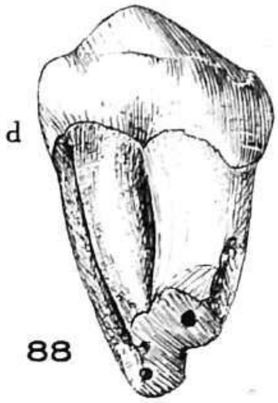
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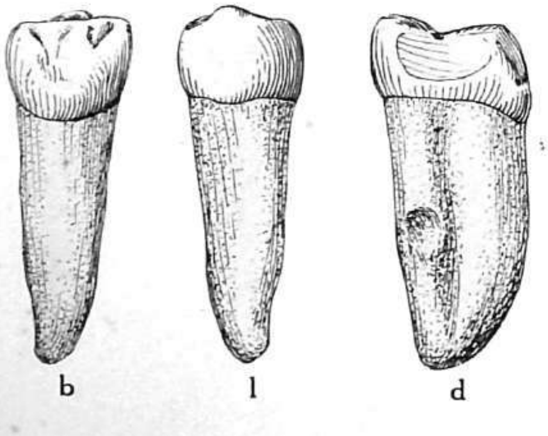
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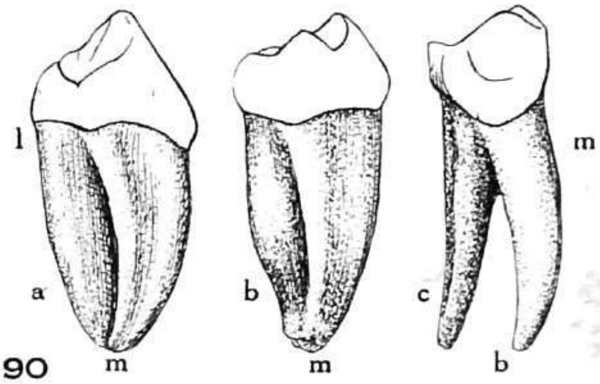
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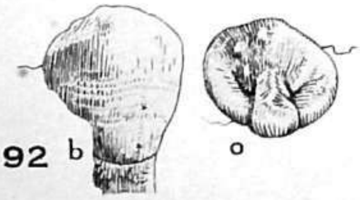
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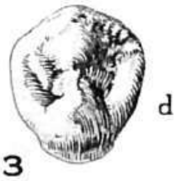
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EXPLANATION OF

PLATE XII

PLATE XII

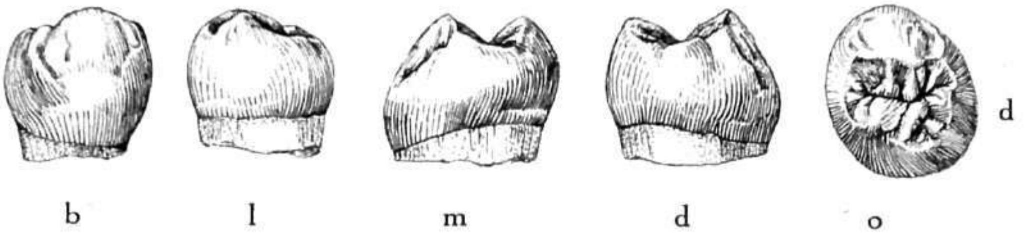
Figure 96. *Sinanthropus 29.* P_3 rt; b, l, m, d, o.

Figure 97. *Sinanthropus 89.* P_3 rt; b, l, m, d, o.

Figure 98. *Sinanthropus 93.* P_3 lt; b, l, m, d, o.

Figure 99. Recent Man (Lenhossek). P_3 rt; b, l, m, o.

Figure 100. Not reproduced.



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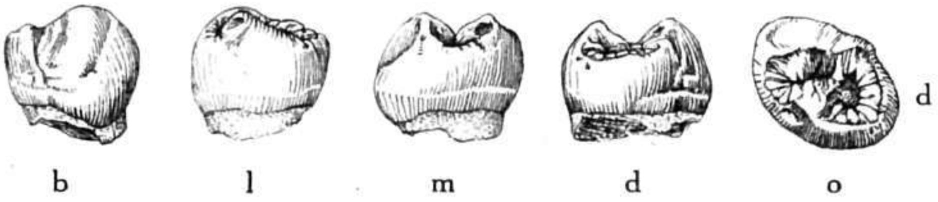

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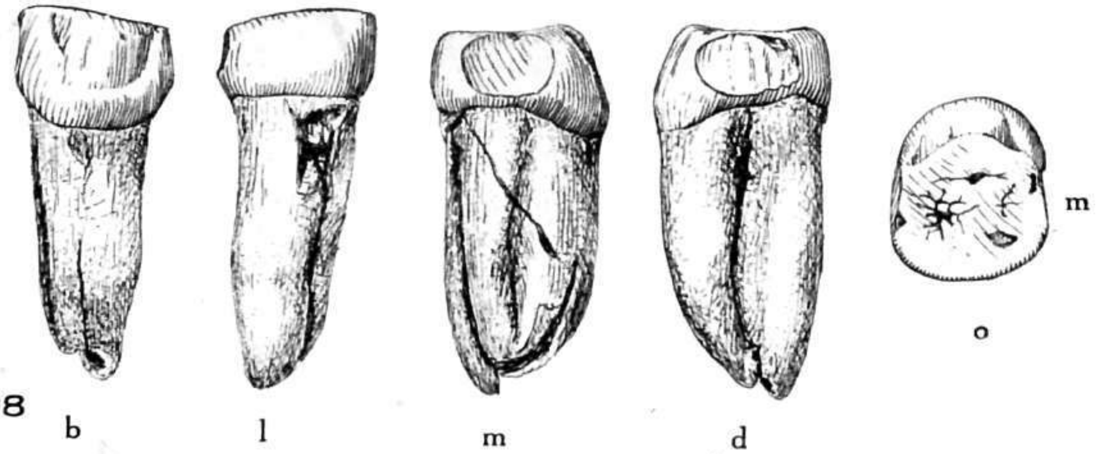

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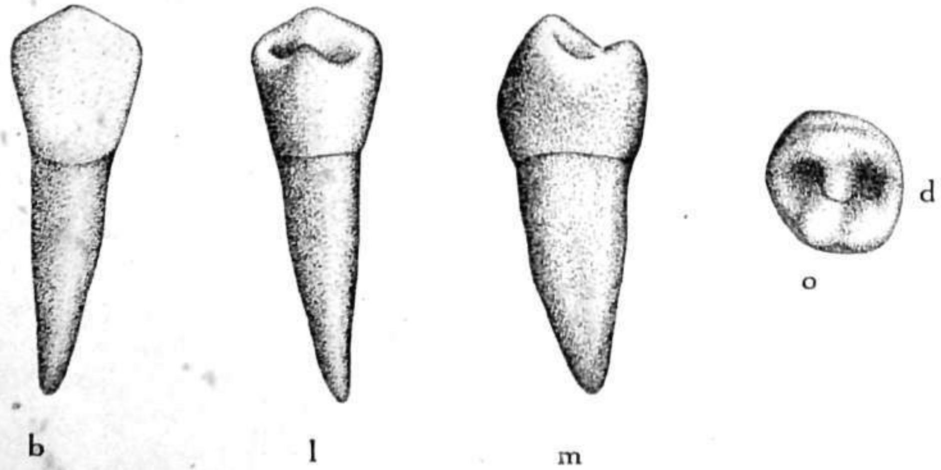

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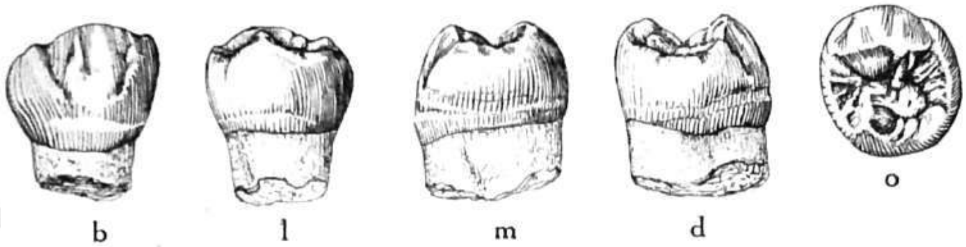
EXPLANATION OF PLATE XIII

PLATE XIII

Figure 101. *Sinanthropus 90.* P_3 rt; b, l, m, d, o.
Figure 102. Chimpanzee juv. ♀ ? (Cat. No. 321). P_3 rt; b, l, m, d, o.
Figure 103. *Sinanthropus* 30. P_3 rt; b, d, o.
Figure 104. Le Moustier P_3 rt, o, from photographs.
Figure 105. Ehringsdorf child P_3 lt, o, from photographs.
Figure 106. Heidelberg P_3 rt, o, after Schoetensack.
Figure 107. Gorilla adult ♂ (Cat. No. 325). P_3 rt, o.
Figure 108. Orang adult ♂ (B). P_3 rt, o.
Figure 109. *Sinanthropus* 33. M^{1}_{x} lt; m, d, o.
Figure 110. The same as fig. 109 with root viewed from below.
Figure 111. *Sinanthropus 95.* M^1 lt, d.
Figure 112. Recent Man (Lenhossek), M_1 rt; o, b, l, m.

Weidenreich—Sinanthropus teeth

Plate XIII, figs. 101-112



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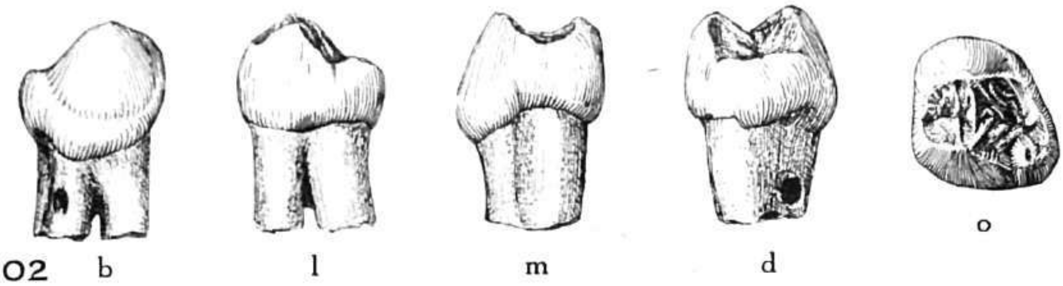

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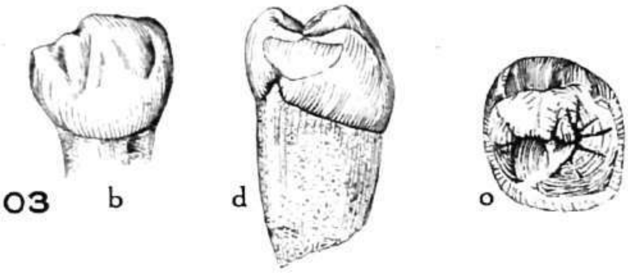

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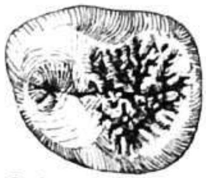

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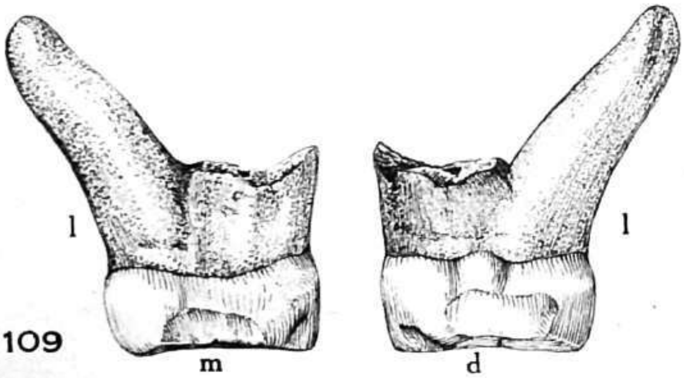

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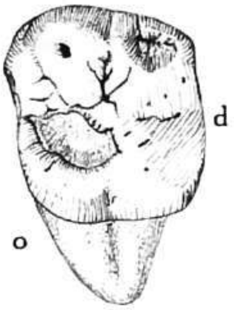

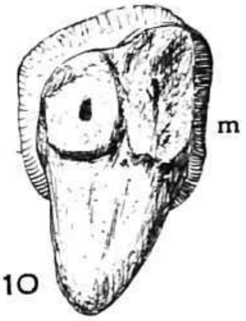

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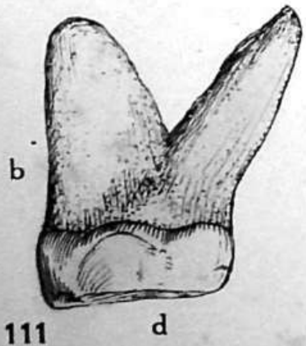

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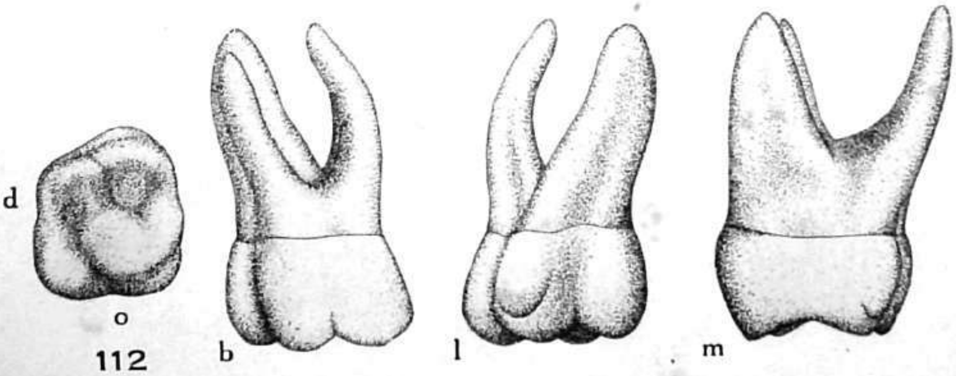

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EXPLANATION OF

PLATE XIV

PLATE XIV

Figure 113. *Sinanthropus* 41. M^2 lt; b, l, m, d, o.

Figure 114. *Sinanthropus* 40. M^2 lt; b, l, m, d, o.

Figure 115. *Australopithecus africanus.* M^1 lt, o. From cast.

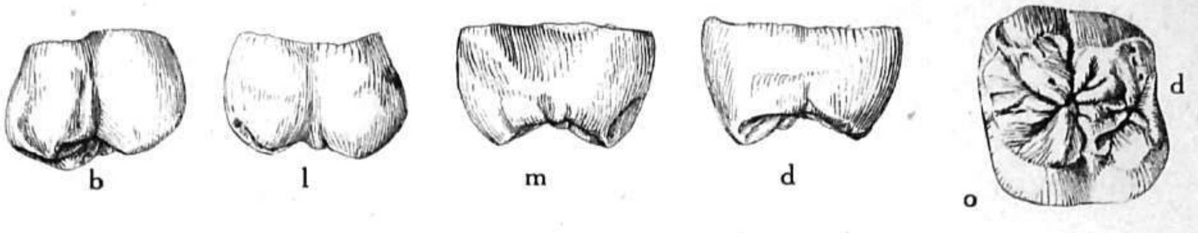
Figure 116. *Dryopithecus germanicus* (Melchingen). Upper M lt, o. From cast and photograph.

Figure 117. Gorilla juv. ♂ (Cat. No. 336). M^1 lt, o.

Figure 118. Gorilla adult ♀ (Cat. No. 323). M^1 rt and M^2 rt; b. 1/1.

Figure 119. *Sinanthropus* 42. M^2 rt; b, l, m, d, o.

Figure 120. *Sinanthropus 104.* M^2 rt; b, l, m, d, o.



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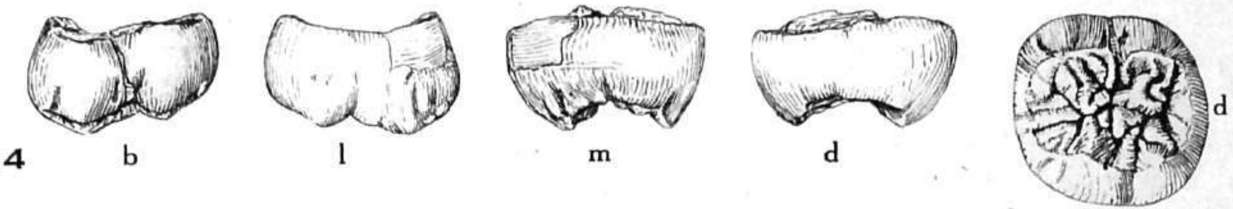

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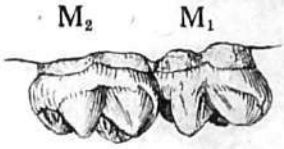

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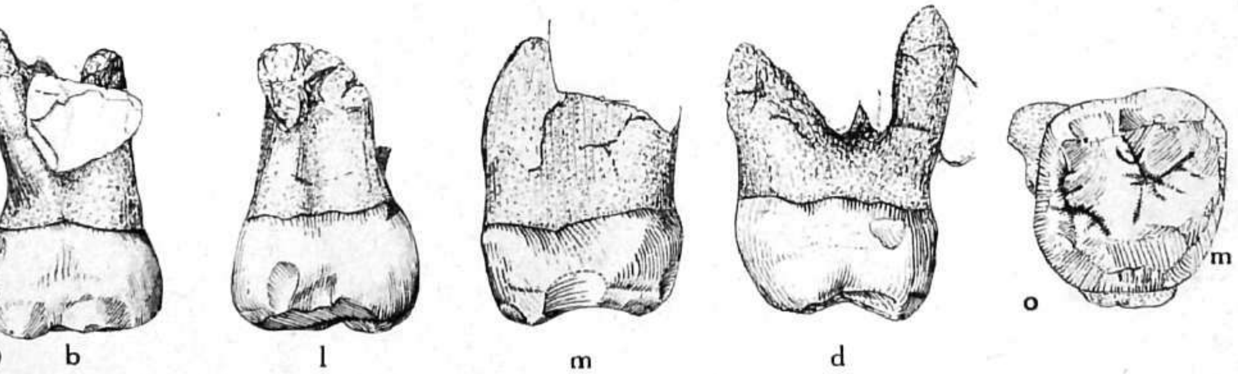

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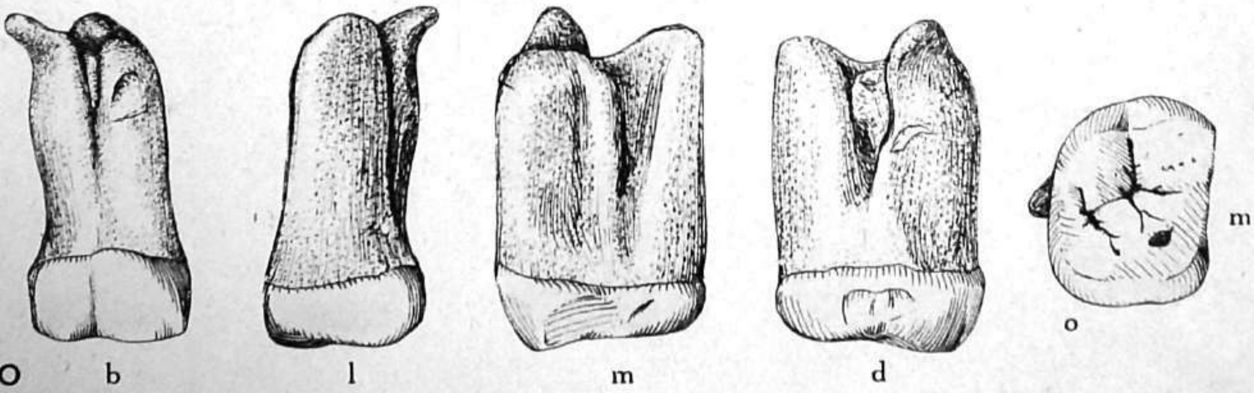

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EXPLANATION OF

PLATE XV

PLATE XV

Figure 121. Recent Man (Lenhossek). M^2 rt; b, l, m, o.

Figure 122. *Sinanthropus 105.* M^2 lt, m.

Figure 123. Krapina M^1 lt, o.

Figure 124. Le Moustier M^2 lt. From photographs.

Figure 125. Recent Orang juv. ♂ M^2 lt, o.

Figure 126. Fossil orang (Kwangsi). M^2 lt, o.

Figure 127. *Sinanthropus* Skull II ♀ (Locus L). The two upper P lt and the three upper M lt *in situ*, 79, *88, 95, 105, 113* (compare fig. 111).[*]

Figure 128. *Sinanthropus* 47. M^3 lt, o.

Figure 129. *Sinanthropus* 48. M^3 rt, o.

Figure 130. *Sinanthropus* 46. M^3 rt; b, l, m, d, o.

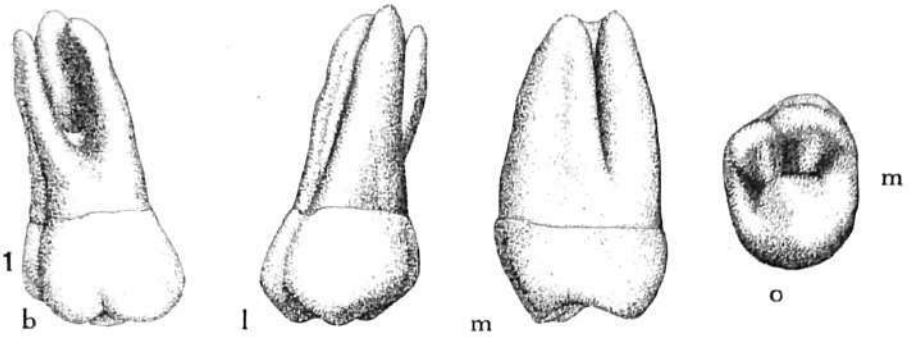
Figure 131. Krapina M^3 rt, after Gorjanovic-Kramberger. Size?

Figure 132. Steinheim M^3 lt, o.

Figure 133. *Symphalangus syndactylus* adult ♂ M^3 rt, o.

Figure 134. *Sinanthropus* (Zdansky). M^3 rt, o, from cast and photograph.

[*] In figure 127 the two premolars are erroneously designated as I^1 and I^2.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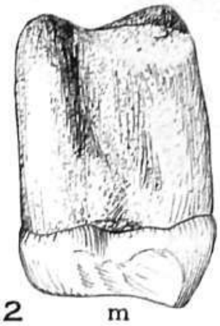
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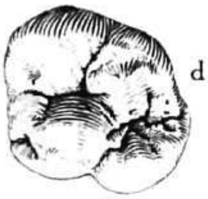
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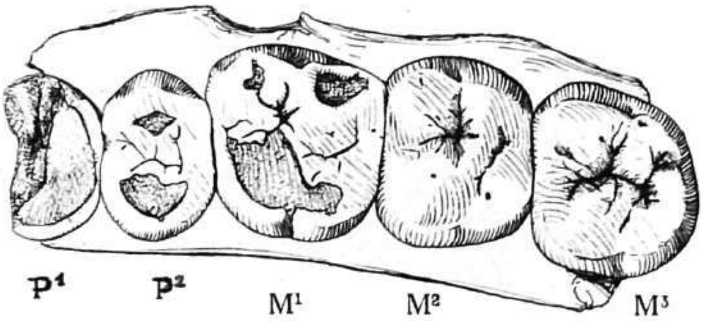
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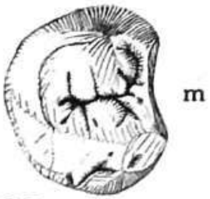
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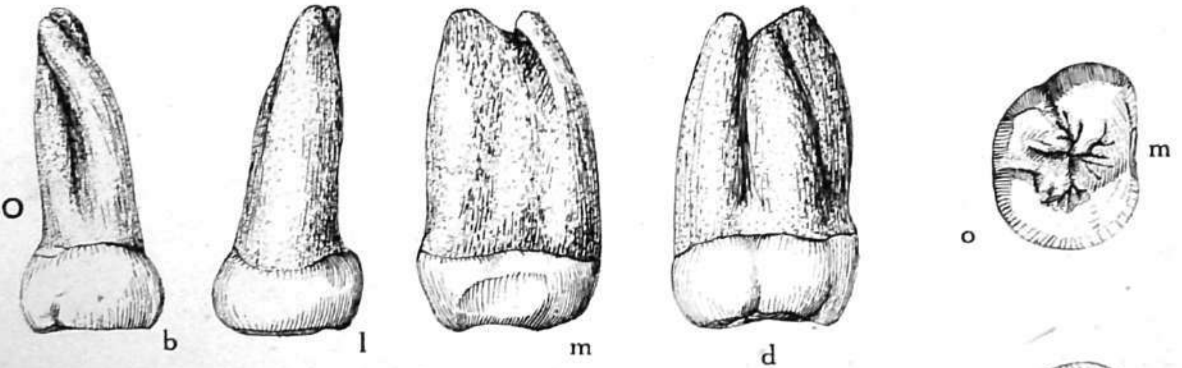
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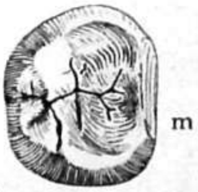
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EXPLANATION OF

PLATE XVI

PLATE XVI

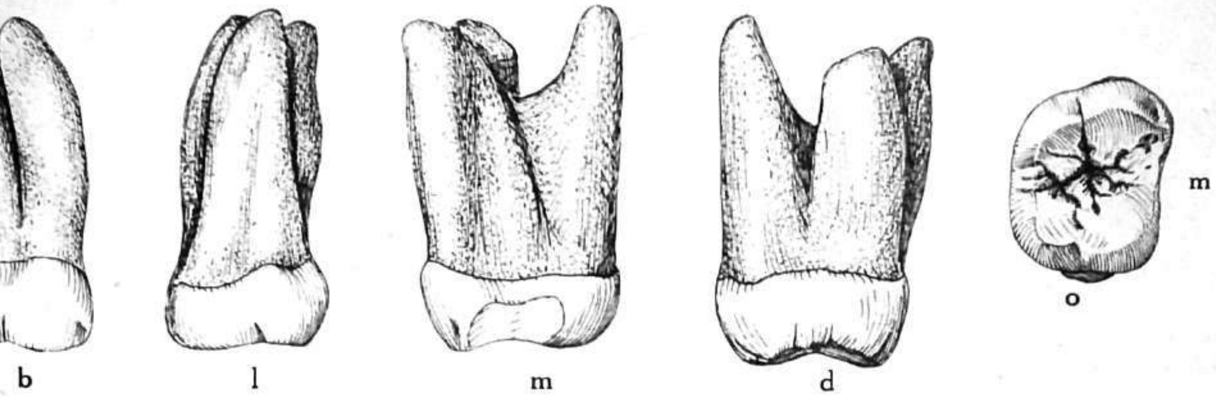
Figure 135. *Sinanthropus 112*. M^3 rt; b, l, m, d, o.

Figure 136. *Sinanthropus* 49. M^3 rt; b, l, m, d, o.

Figure 137. Recent Man (Lenhossek). M^3 rt; b, l, m, o.

Figure 138. *Sinanthropus* 37. M_1 rt. Distal moiety viewed from mesial side showing the exposed pulp cavity in bucco-lingual diameter and the thickness of the enamel and dentine.

Figure 139. *Sinanthropus* 36. M_1 lt; b, l, m, d, o.



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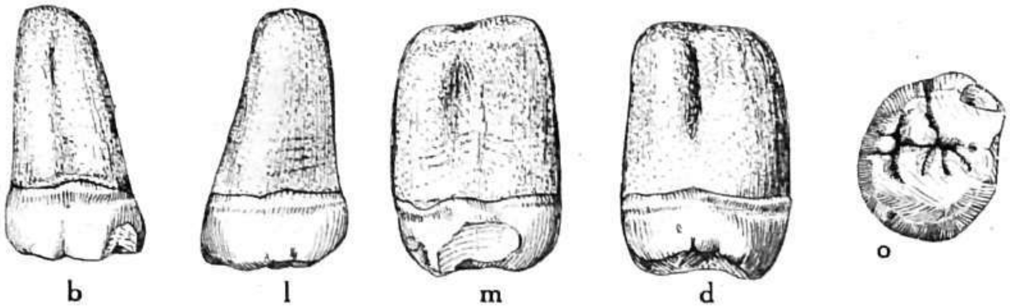

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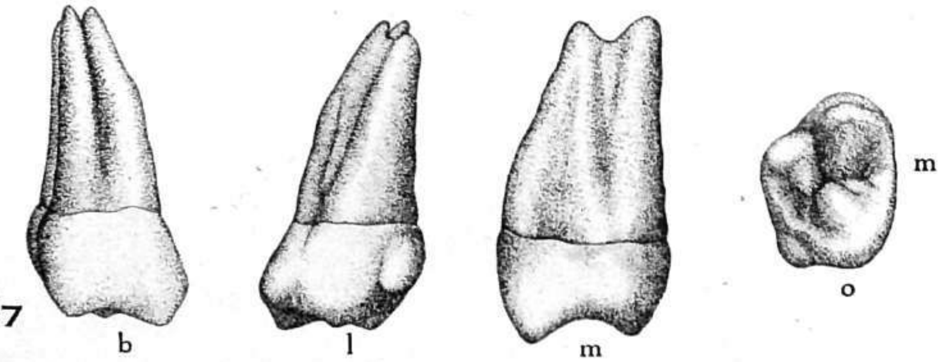

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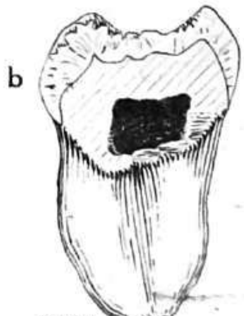

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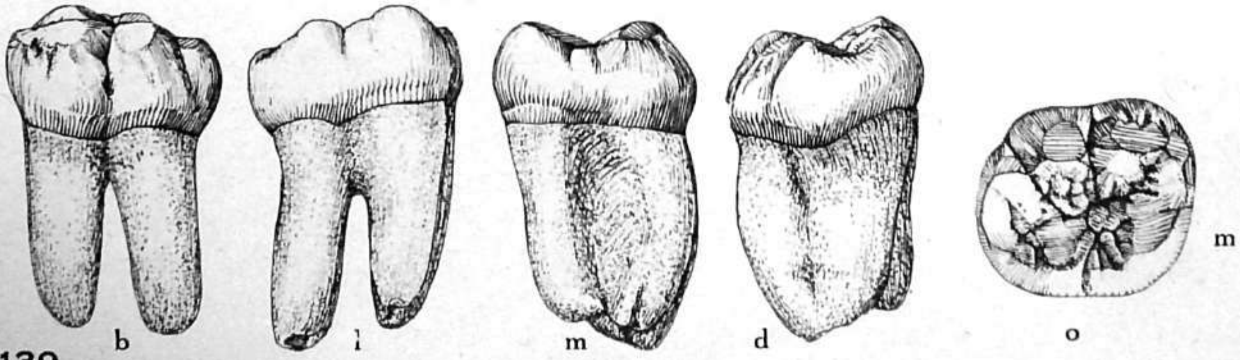

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EXPLANATION OF PLATE XVII

PLATE XVII

Figure 140. *Sinanthropus 98.* M_1 rt; b, l, d, o.

Figure 141. *Sinanthropus 102.* M_1 lt; b, l, m, d, o.

Figure 142. *Sinanthropus* 38. M_1 lt; b, l, m, d, o.

Figure 143. Recent Man (Lenhossek). M_1 rt; b, l, m, o.

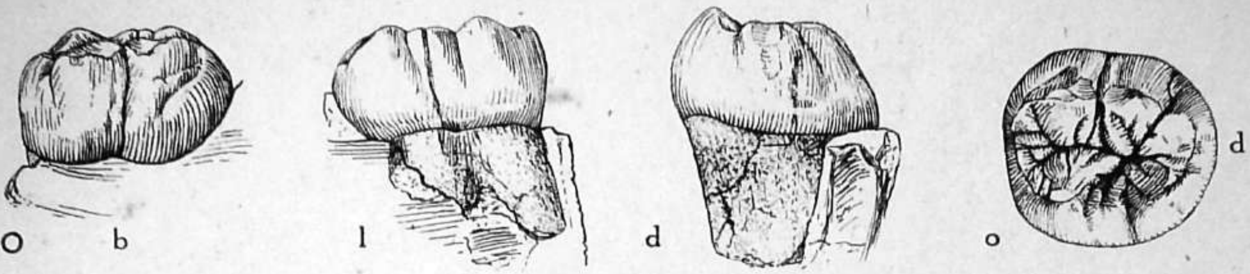
Figure 144. *Sinanthropus* 34 (isolated molar described by Davidson Black). M_1 lt, o.

Figure 145. *Sinanthropus 97.* M_1 rt, o.

Figure 146. Comparative buccal views of M_1 lt of palæolithic man—Choukoutien "Upper Cave" (a); recent Australian Aboriginal (b); recent Eskimo (c); Chimpanzee juv. ♂ (d); Gorilla adult ♂ (e). 1/1

Weidenreich—Sinanthropus teeth

Plate XVII, figs. 140-146



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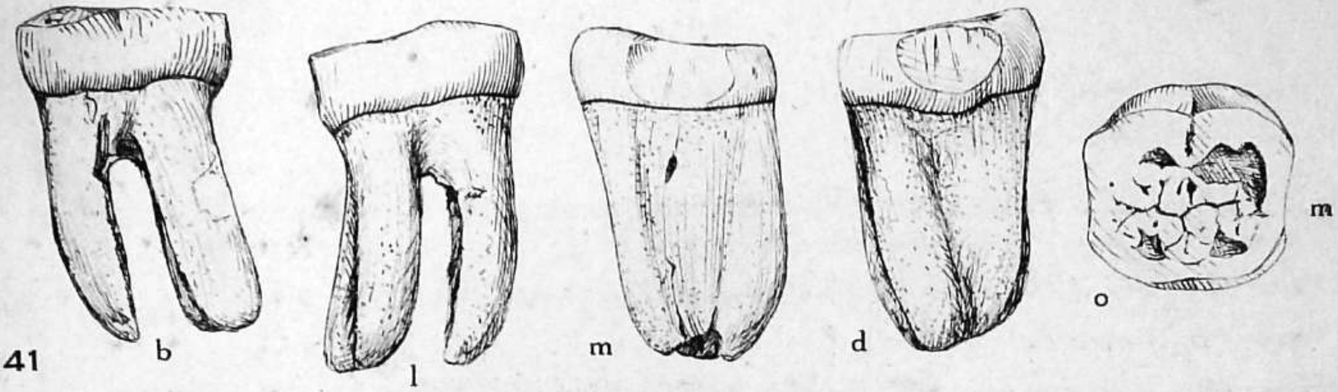

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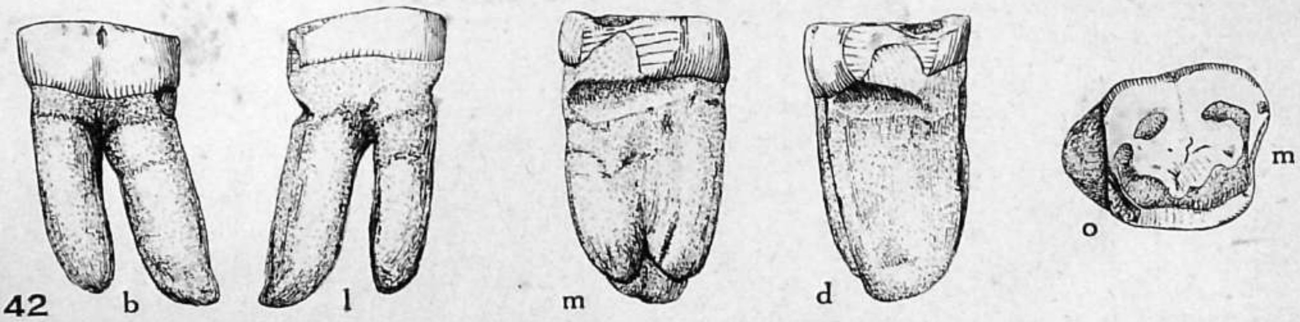

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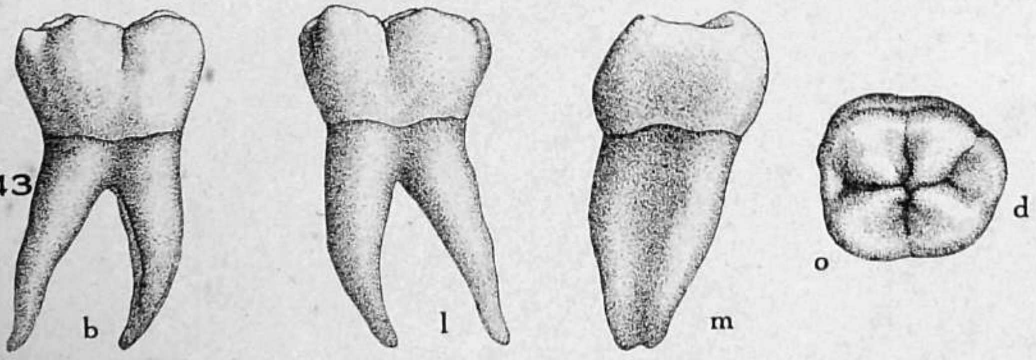

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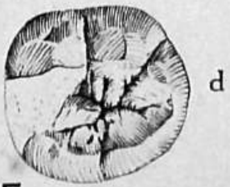

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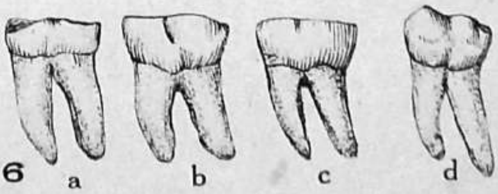

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EXPLANATION OF

PLATE XVIII

PLATE XVIII

Figure 147. *Sinanthropus* 35. M_1 rt; b, m, o.

Figure 148. *Sinanthropus* 99. M_1 rt; b, l, m.

Figure 149. Gibraltar child M_1 rt, o; from cast.

Figure 150. Krapina M_1 lt; after Gorjanovic-Kramberger.

Figure 151. Ehringsdorf child M_1 lt; from photographs.

Figure 152. Heidelberg M_2 rt; after Schoetensack.

Figure 153. Taubach M_1 lt; b, m, o; from photographs.

Figure 154. Le Moustier M_1 rt (a); M_2 rt (b); from photographs and after Aichel.

Figure 155. Schema of wrinkles of a lower molar of *Sinanthropus* on the basis of a hypothetical M_1 lt, like those of figures 165, o and 166.

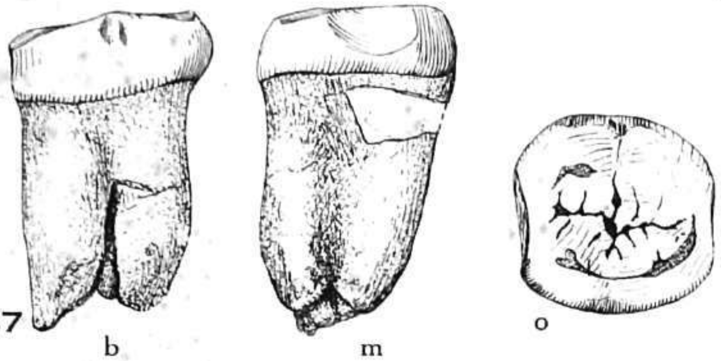
Figure 156. *Australopithecus africanus.* M_1 rt, o; from cast.

Figure 157. Gorilla juv. ♂ (Cat. No. 336). M_1 rt, o.

Figure 158. Chimpanzee juv. (Cat. No. 381). M_2 rt, o.

Figure 159. *Dryopithecus germanicus* (Trochtelfingen). M_1 lt, o.

Figure 160. *Hylobates mülleri* juv. M_1 rt, o.



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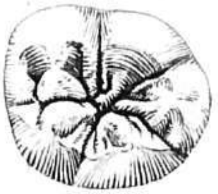

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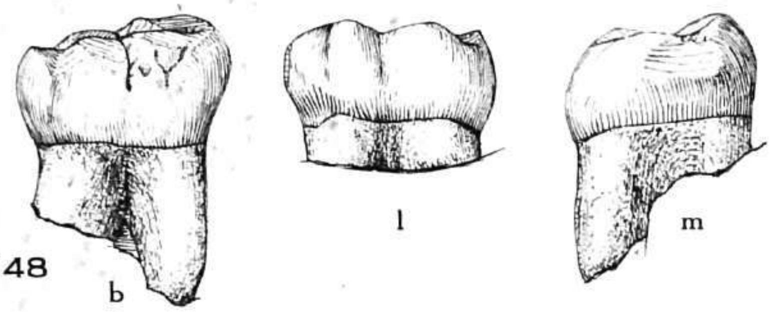

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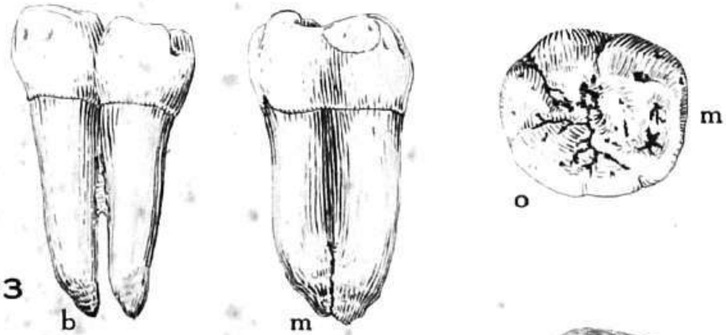

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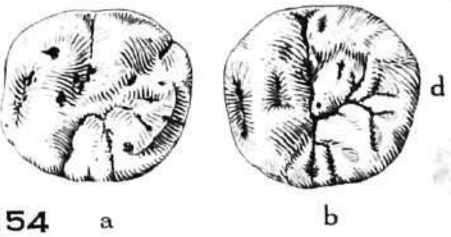

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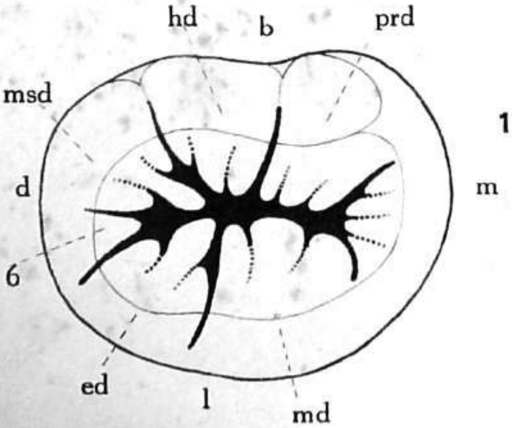

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EXPLANATION OF
PLATE XIX

PLATE XIX

Figure 161. *Sinanthropus* 45. M_3 rt; b, l, m, d, o.

Figure 162. Recent Man (Lenhossek). M_2 rt; b, m, l, o.

Figure 163. *Sinanthropus 108.* M_3 rt, o.

Figure 164. *Sinanthropus 107.* M_3 rt, o.

Figure 165. *Sinanthropus* 44. M_3 lt; b, l, o.

Figure 166. *Sinanthropus* 43. M_3 lt, o.

Figure 167. Ehringsdorf child M_3, lt, o, from photographs.

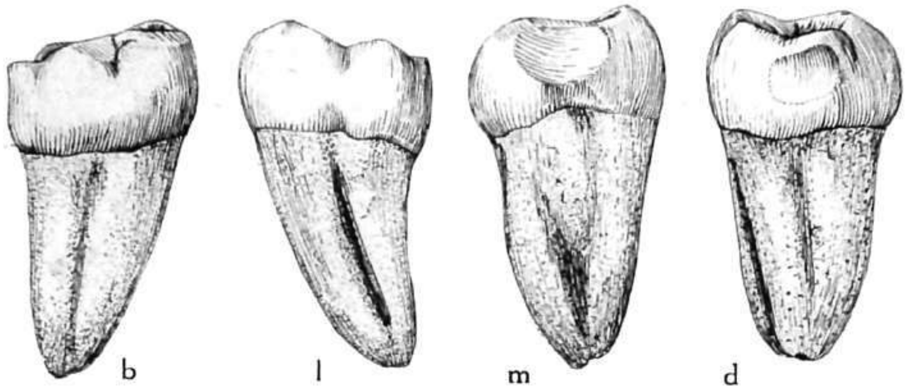
Figure 168. Gibraltar child M_3 rt, o. *Note:* through an oversight the buccal side is turned downwards.

Figure 169. Recent European M_3 lt, o.

Figure 170. Palæolithic Man—Choukoutien "Upper Cave" M_3, rt, o; (a and b).

Figure 171. Prehistoric Chinese (Mongol Cat. No. 157). M_1 rt, o.

Figure 172. *Sinanthropus 114.* M_3 rt; b, l, m, d (compare figs. 173 and 181).



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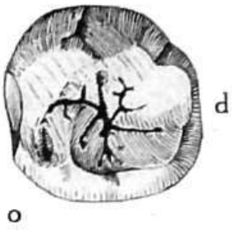

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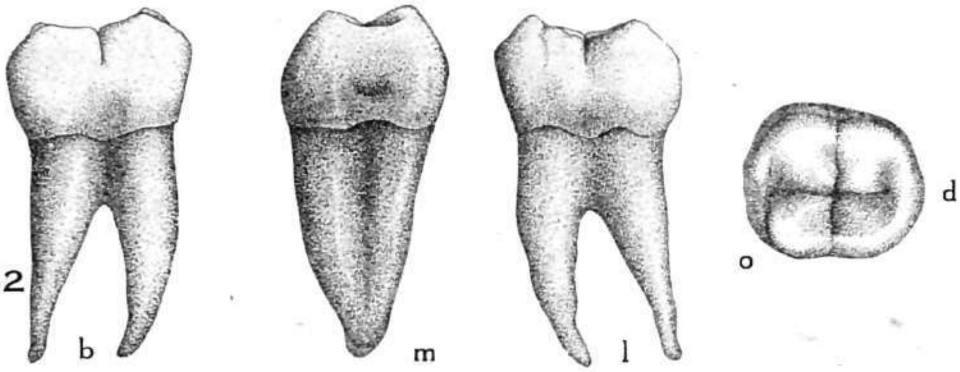

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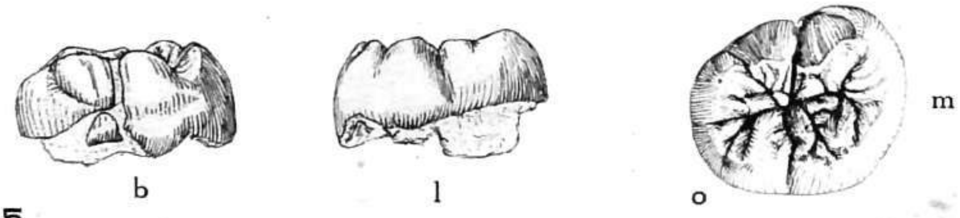

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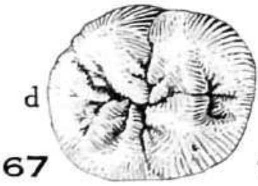

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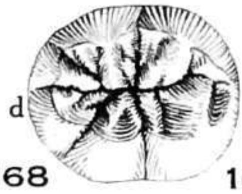

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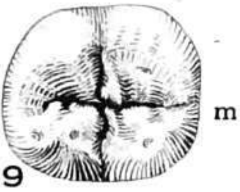

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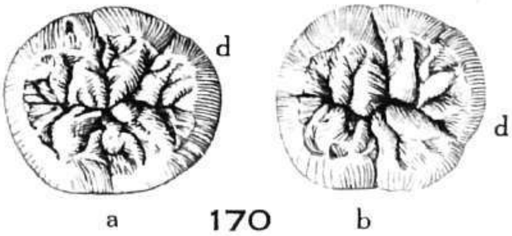

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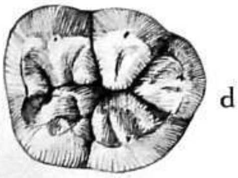

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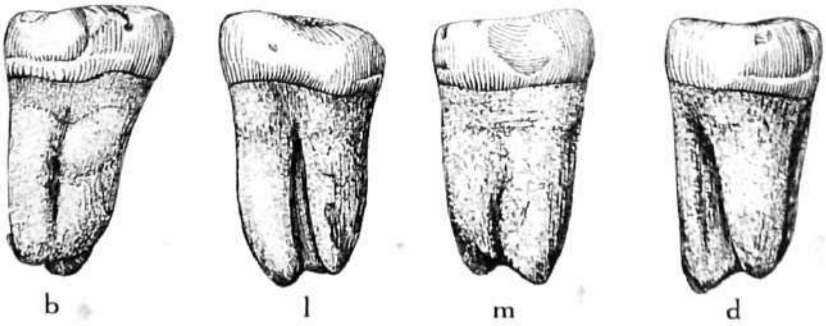

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EXPLANATION OF
PLATE XX

PLATE XX

Figure 173. *Sinanthropus 114.* M_3 rt; a) roots viewed from below; *o)* occlusal view (compare figs. 172 and 181).

Figure 174. *Sinanthropus 115.* M_3 rt, o.

Figure 175. *Sinanthropus 116.* M_3 lt, o.

Figure 176. *Sinanthropus* 50. M_3 lt; b, l, m, d, o.

Figure 177. *Sinanthropus* 52. M_3 lt; b, l. m, d, o.

Figure 178. Recent Man (Lenhossek). M_2 rt; b, l, m, o.

Figure 179. Fossil orang (Kwangsi). M_3 lt, o.

Figure 180. *Sinanthropus 96* M_1, *106* M_2, *114* M_3, rt side; b, three molars of jaw A II (compare figs. 172 and 173).

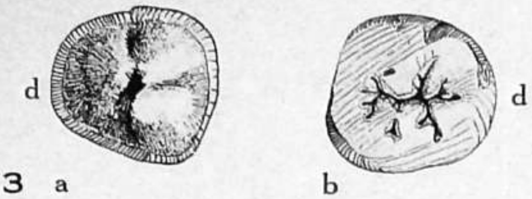
Figure 181. Gorilla ♀ (Cat. No. 325). C_1, P_1, P_2, M_1 and M_2, lt side. 1/1

Figure 182. Heidelberg M_3 rt after Schoetensack.

Figure 183. Krapina M_3 rt after Gorjanovic-Kramberger.

Figure 184. Pithecia M_2 rt after Branca (1898). 5/1.

Figure 185. Le Moustier M_3 rt from photographs and after H. Virchow.



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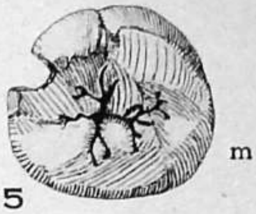

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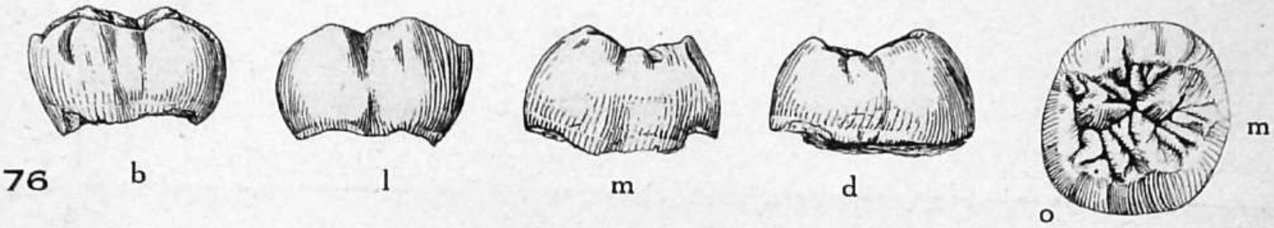

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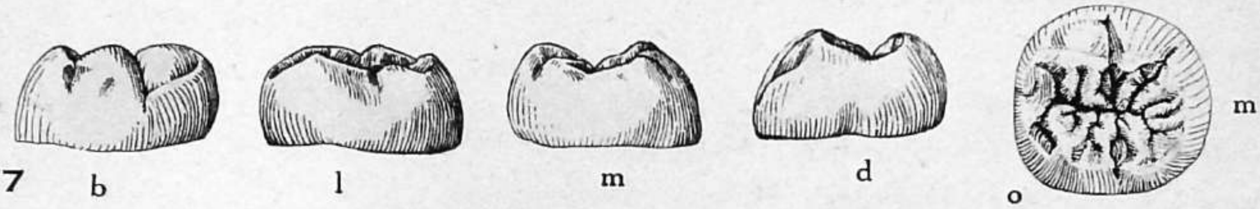

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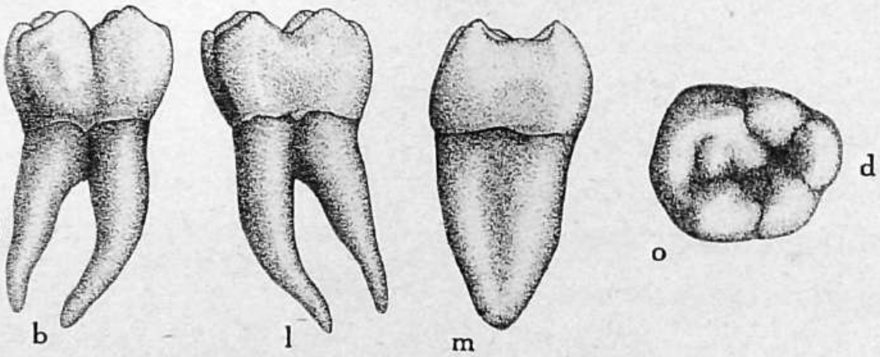

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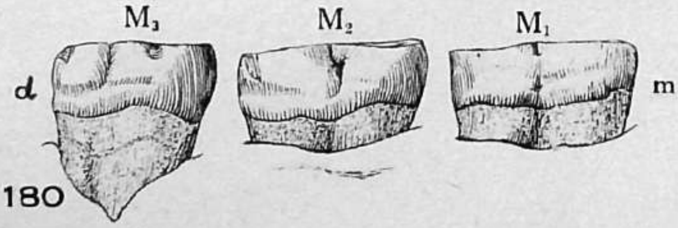

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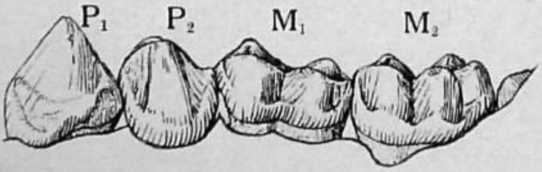

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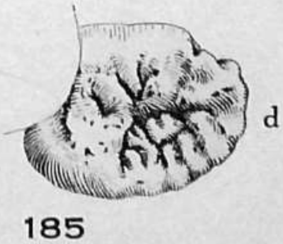

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EXPLANATION OF

PLATE XXI

PLATE XXI

Figure 186. *Sinanthropus 118.* i_1 rt; b, l, m, d, o.

Figure 187. Recent Man (Lenhossek). i_1 rt; b, m, l.

Figure 188. *Sinanthropus 120.* c, rt; b, l, m, d, o.

Figure 189. Recent Man (Lenhossek). c, rt; b, m, l.

Figure 190. *Sinanthropus 122.* c, lt; b, l, m, d.

Figure 191. *Sinanthropus 121.* c, rt, l.

Figure 192. Fossil orang (Kwangsi). c, lt; b, l, m, d, o.

Figure 193. Crown and root of: (a) recent man (Lenhossek) c, rt; (b) *Sinanthropus 120*, c, rt based on the skiagram.

Figure 194. *Sinanthropus 125.* m_1 rt; b (- - reconstructed cusp), l, m, d, o.

Figure 195. Orang (No. 246) m_1 rt, o.

Figure 196. *Australopithecus africanus.* m_1 rt, b; after cast.

Figure 197. Orang (No. 19) m_1 rt, b.

Figure 198. Recent Man (Lenhossek) m_1 rt; b, m, l, o.

Figure 199. *Sinanthropus* 121. m_1 and m_2 rt, o.

Figure 200. Gorilla ♂ (No. 330) m_1 and m_2 rt, o.

Figure 201. *Australopithecus africanus* m_1 and m_2 rt, o, after cast.

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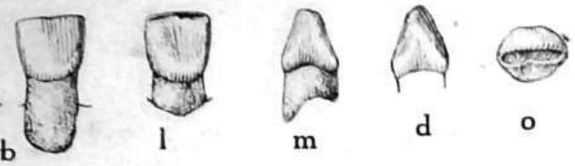

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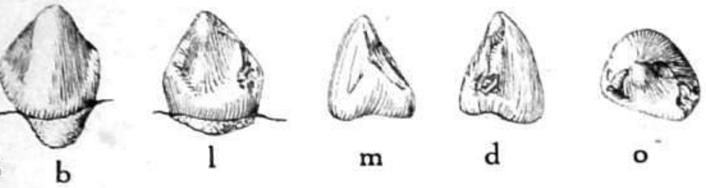

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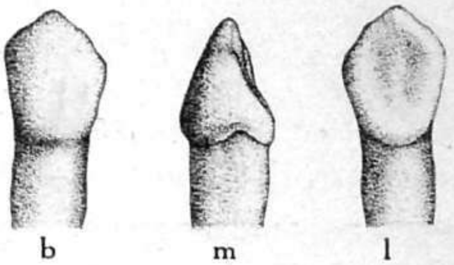

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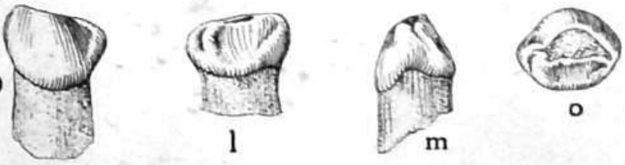

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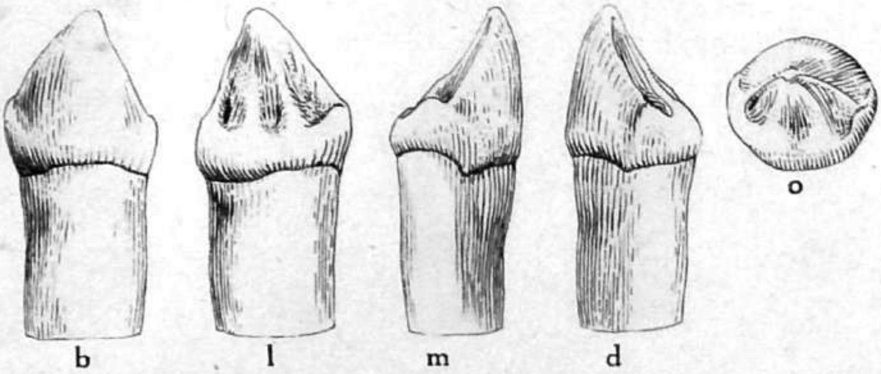

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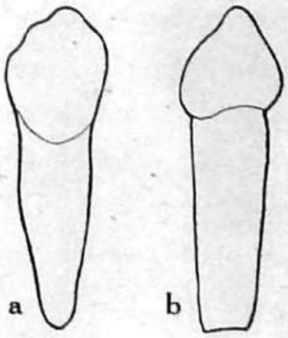

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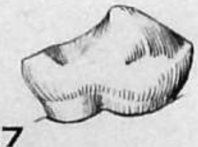

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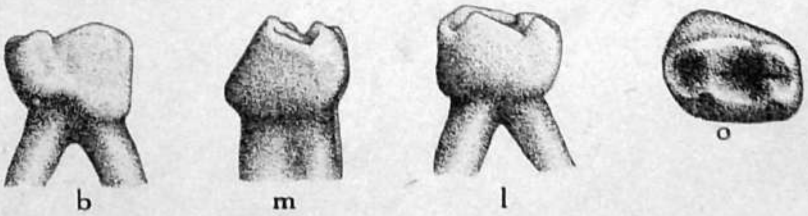

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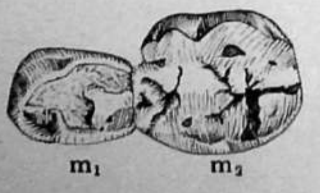

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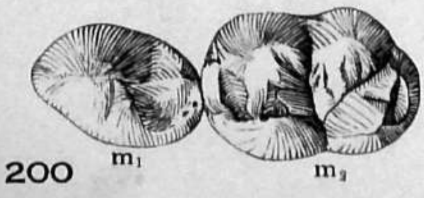

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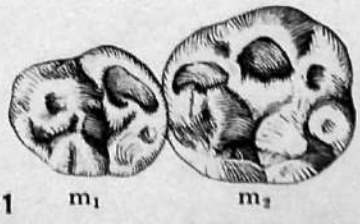


EXPLANATION OF

PLATE XXII

PLATE XXII

Figure 202. *Sinanthropus* 128. m_2 rt; b, l, m, d, o.

Figure 203. *Sinanthropus* 129. m_1 rt; o.

Figure 204. *Sinanthropus* 127. m_2 rt; o.

Figure 205. Gibraltar child m_1 lt and m_2 lt; o.

Figure 206. Recent Man; North Chinese child m_1 and m_2 rt; o.

Figure 207. Recent Man (child) m_2 rt after Lenhossek; b, m, d, o.

Figure 208. Gorilla child ♂ (No. 336) m_2 rt; o,

Figure 209. Gibraltar child m_1 lt and m_2 lt, b.

Figure 210. Gibraltar child (No. 330) m_1 rt and m_2 rt; b.

Figure 211. m_2 rt with root in buccal view: (a) Recent Man after Lenhossek; (b) *Sinanthropus* 128 (cf. fig. 202) drawn from skiagram (fig. 303).

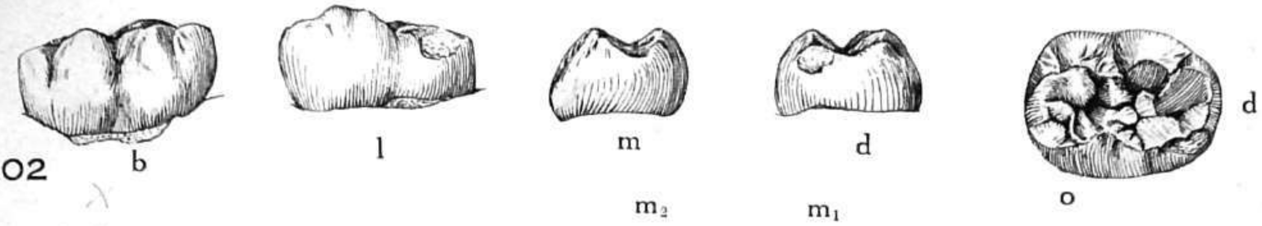
Figure 212. m_2 rt of chimpanzee child ♂ to demonstrate the differences in form; (a) No. 427, (b) No. 18.

Figure 213. Piltdown "C" after Dawson and Woodward, 1914, pl. XV. figs. 2 a and b; b, l, s—skiagram (pl. XV, fig. 3 b). 1/1.

Figure 214. *Sinanthropus* 28. P^2 rt; m, o.

Figure 215. Indents at the tooth neck; (a) La Quina M_1 lt after H. Martin (1923); (b) recent man M_1 rt, m; (c) M^3 rt, d.

Figure 216. Piltdown mandible, lower molars: (a) M_1 lt, o, (b) M_1 and M_2 rt, o.



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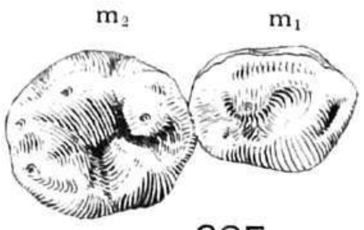

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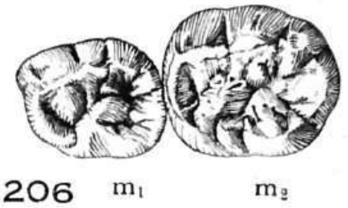

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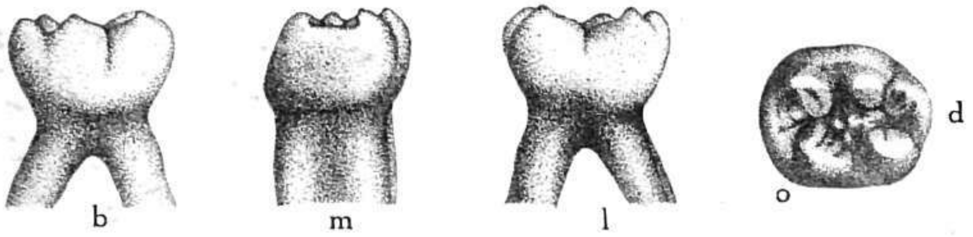

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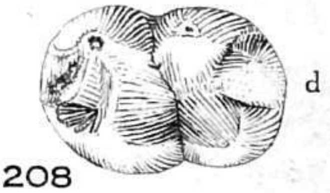

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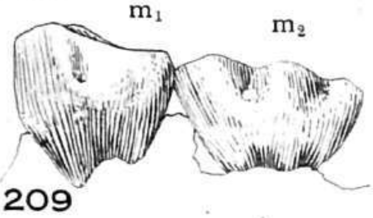

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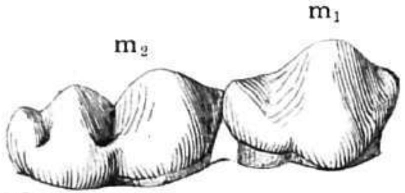

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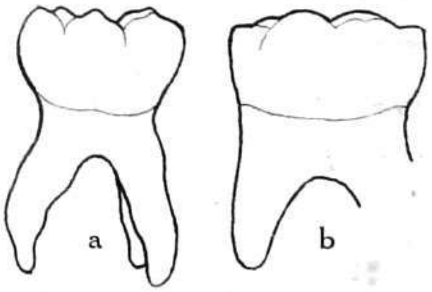

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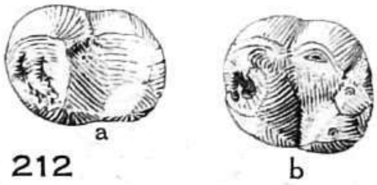

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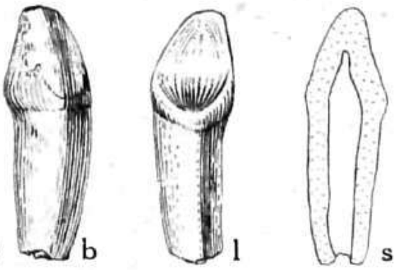

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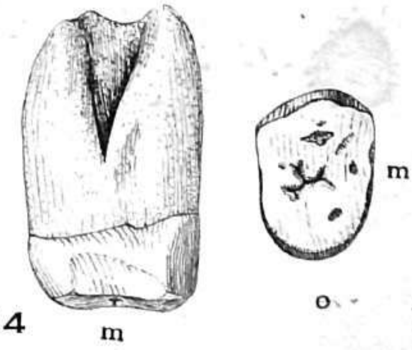

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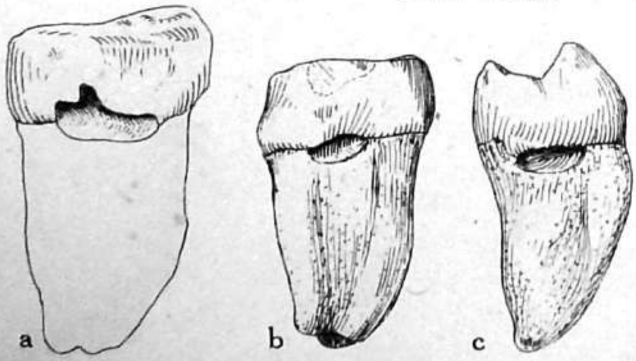

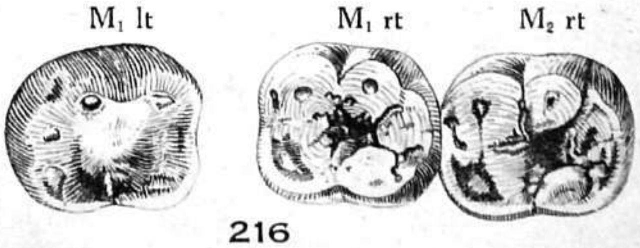

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EXPLANATION OF

PLATE XXIII

PLATE XXIII

Figure 217. Diagram: sagittal section through the alveolar part and midline of the left upper central incisor of an adult male chimpanzee (London) orientated in the Frankfort plane. The alveolar plane of the upper jaw with contours of the left row of teeth from C' to M^3 is also given. 1/1.

Figure 218. The same diagram as in figure 217 of a juvenile male gorilla (No. 325) with all permanent teeth, with the exception of the canine. 1/1.

Figure 219. The same diagram as in figure 217 of an adult female orang (No. 425). 1/1.

Figure 220. The same diagram as in figure 217 of a second adult female orang (Borneo). 1/1.

Figure 221. The same as in figure 217 of an adult recent Australian Aboriginal (♂ No. 668) with strong alveolar prognathism. 1/1.

Figure 222. The same as in figure 217 of an adult recent North Chinese (♂, No. 191) with strong alveolar prognathism. 1/1.

Figure 223. The same as in figure 217 of an adult recent North Chinese (♂, 145) with orthognathism. 1/1.

Figure 224. Diagram: sagittal section through the midline of the left central incisor and the frontal part of the mandible of an adult female gorilla (No. 324) orientated in the alveolar plane of the mandible. The longitudinal axis of the incisor is indicated by interrupted lines. 1/1.

Figure 225. The same as in figure 224 of an adult male chimpanzee (London); compare figure 217. 1/1.

Figure 226. The same as in figure 224 of an adult female orang (Borneo); compare figure 220. 1/1.

Figure 227. The same as in figure 224 of an adult male Hylobates concolor. 1/1.

Figure 228. The same as in figure 224 of *Sinanthropus* mandible Locus G I. 1/1.

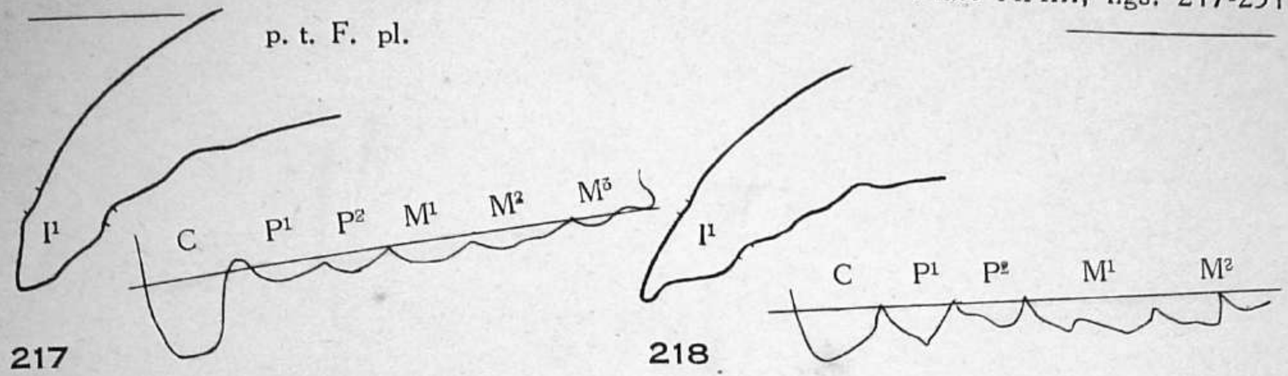
Figure 229. The same as in figure 224 of the Heidelberg mandible. 1/1.

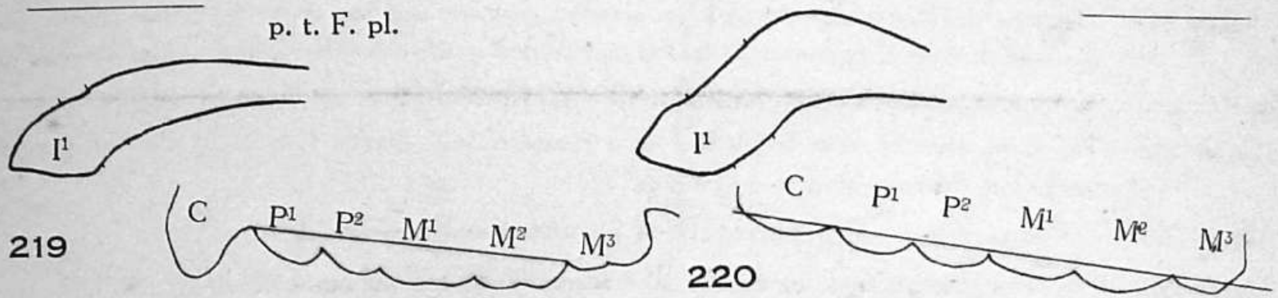
Figure 230. The same as in figure 224 of an adult prehistoric female Chinese (Kansu, No. 404/7). 1/1.

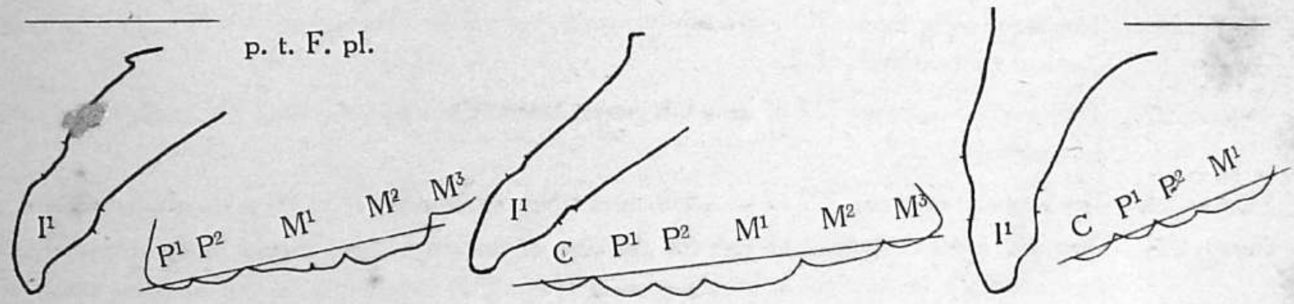
Figure 231. The same as in figure 224 of an adult recent man (♀ European). 1/1.

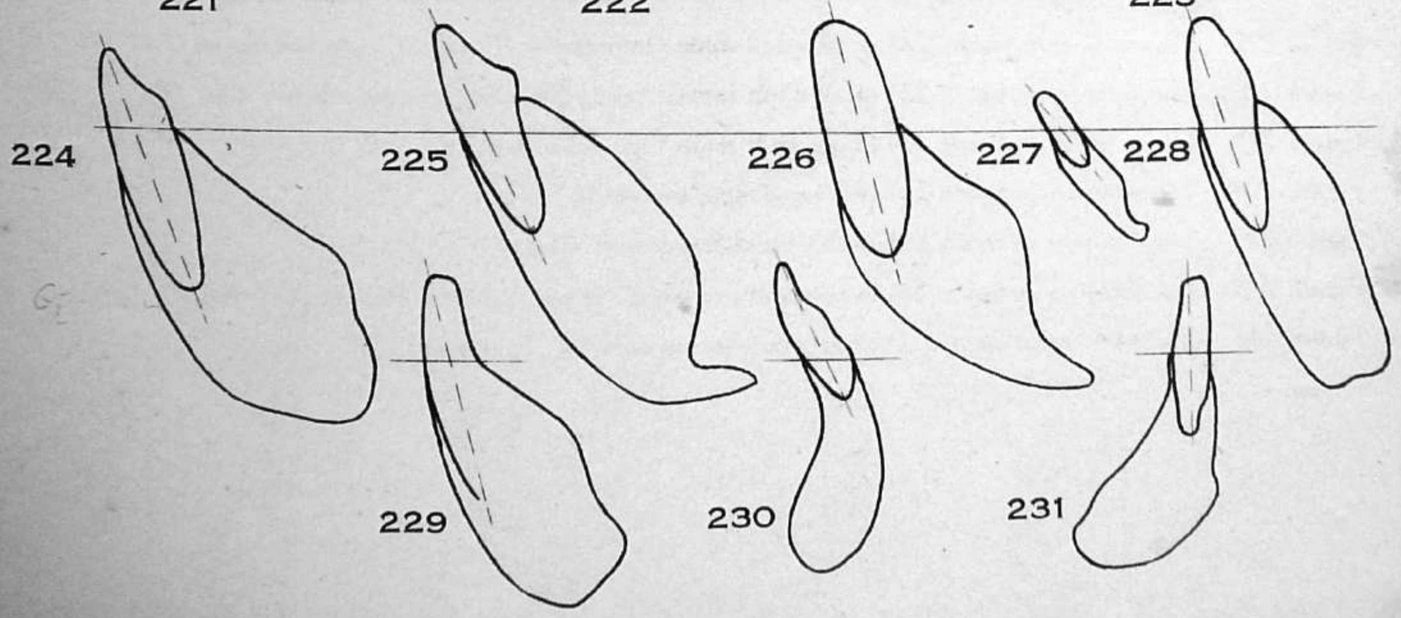
Weidenreich—Sinanthropus teeth

Plate XXIII, figs. 217-231









EXPLANATION OF
PLATE XXIV

PLATE XXIV

Figure 232. Sagittal sections through the left upper central incisor and the corresponding alveolar part to demonstrate its position within the jaw in Frankfort orientation. 1/1. a, adult female orang (compare fig. 220); b, adult female orang (compare fig. 219); c, juvenile male gorilla (compare fig. 218); d, adult male chimpanzee (compare fig. 217); e, recent man: prognathous North Chinese (compare fig. 222); f, recent man: prognathous Australian Aboriginal (compare fig. 221); g, recent orthognathous European male; h, orthognathous recent North Chinese (compare fig. 223).

Figure 233. (a-h), the same sections as in figure 232 in alveolar orientation.

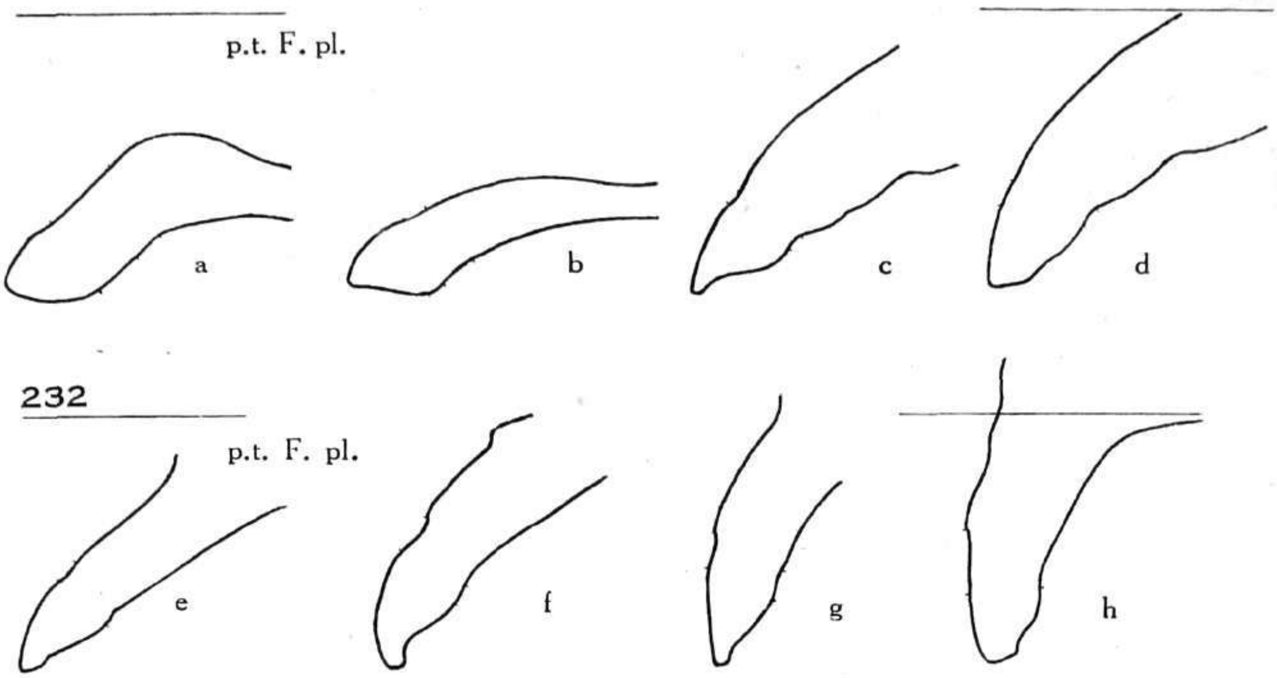
Figure 234. Cross section in bucco-lingual direction through M_1 after Rebel's (1931) figure 2502 (p. 2305).

Figure 235. Drawing from a skiagram of M_1 and M_2 of a Krapina mandible after Gorjanovic-Kramberge (1910). 1/1.

Figure 236. Drawing from a skiagram of m_1 and m_2 of the mandible of the Gibraltar child after Buxton (1928). 1/1.

Figure 237. Drawing of a skiagram of M_1-M_3 lt of the mandible of La Quina after H. Martin (1923). 1/1.

Figure 238. Drawing from a skiagram of P_1-M_1 lt of the adult mandible of Ehringsdorf after H. Virchow (1920). 1/1.



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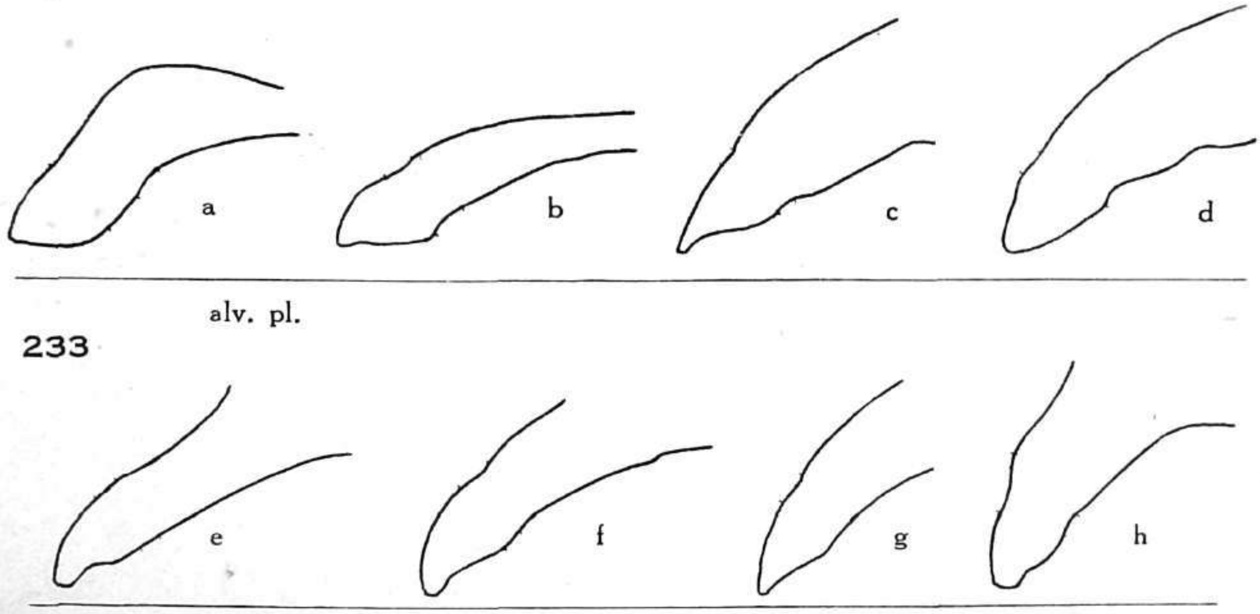

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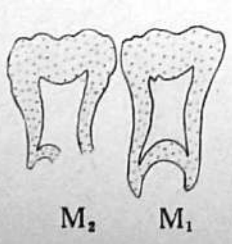

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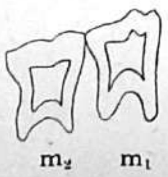

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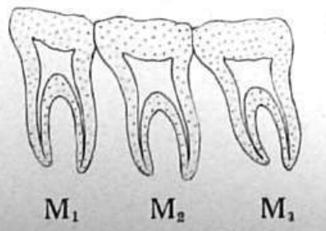

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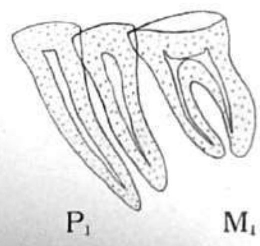

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EXPLANATION OF

PLATE XXV

PLATE XXV

Figure 239. A series of upper and lower teeth of recent man (a) according to figure 518 in Spalteholz's Atlas (Vol. 2) orientated parallel to the cutting edge and Sinanthropus (b) composed of individual large types of teeth and orientated parallel to the boundary of the enamel. 1/1.

Figure 240. Lower canine and premolars of a mandible of *Dryopithecus fontani* after Gaudry's (1878) figure 310. 1/1. c, buccal view; b, occlusal view.

Figure 241. Lower canine and premolars of a mandible of *Dryopithecus cautleyi* after Gregory and Hellman's (1926) figure 12. 1/1. a, buccal view; b, occlusal view.

Figure 242. Teeth attributed to *Pithecanthropus* compared with correspondingly worn teeth of *Sinanthropus*. a, P_1 lt of *Pithecanthropus;* a′, P_1 rt of *Sinanthropus* 24 (mirror image); b, M^3 rt of *Pithecanthropus*, b′, M^3 rt of *Sinanthropus 112*.

Figure 243. M_1 lt (a) of a ♂ fossil orang (cave of Kunming, Yünnan) compared with the same tooth (b) of a ♂ recent orang (No. 231).

Figure 244. Drawings of skiagrams: (a) C, of *Sinanthropus 75* (♂), (b) C, of a female orang (Borneo), (c) I^2 of the same orang. 1/1.

Figure 245. C, lt of a female chimpanzee viewed from lingual and mesial side after Remane (1927). 1 1/2:

Figure 246. C′ lt of a female chimpanzee after Remane (1927); b, m, l. Size?

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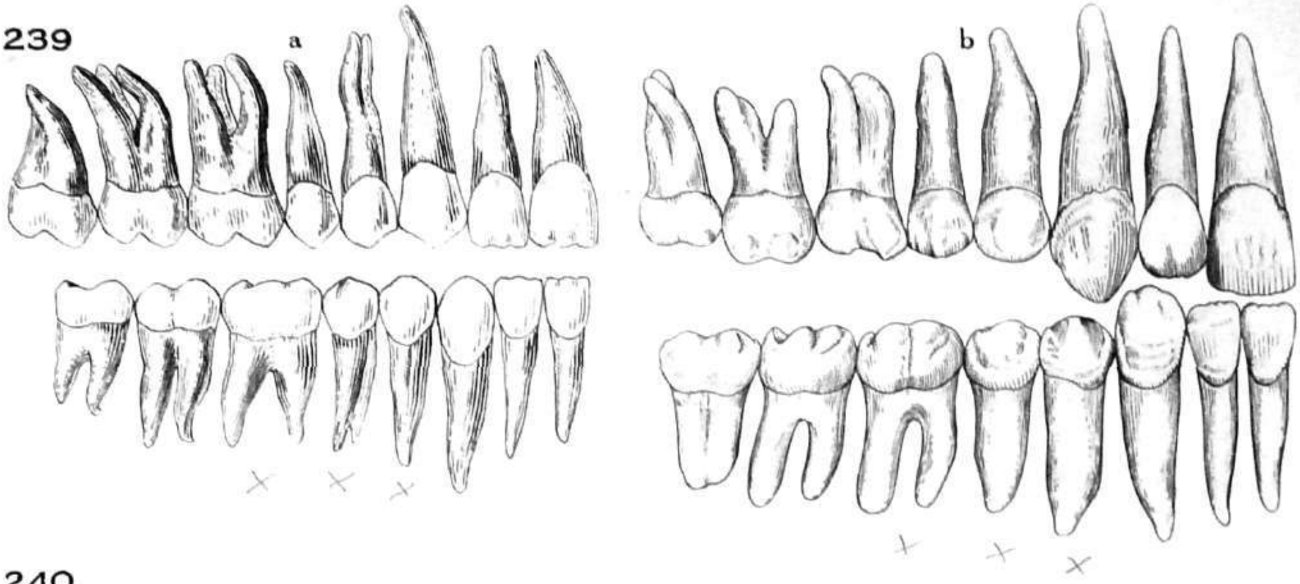

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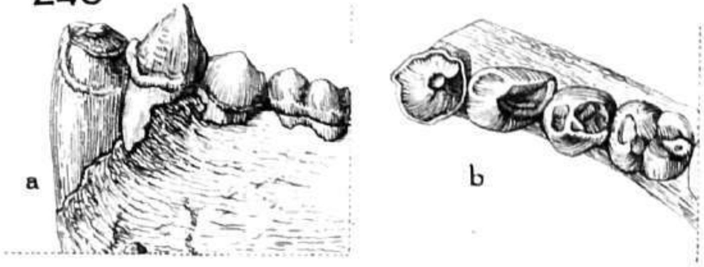

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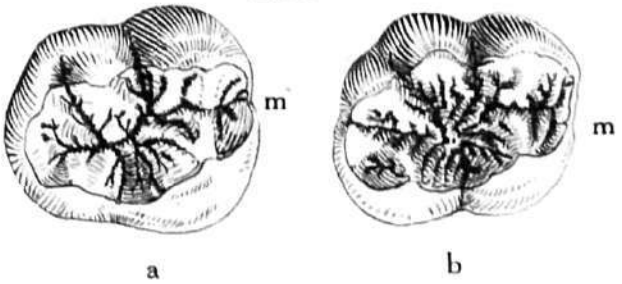

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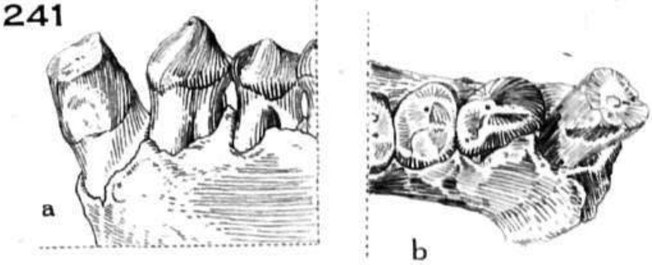

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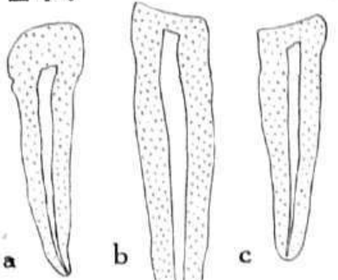

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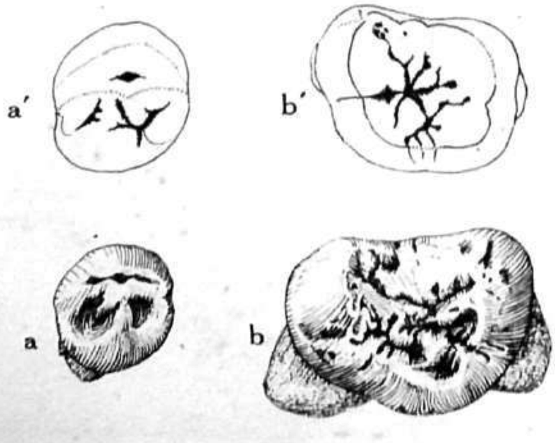

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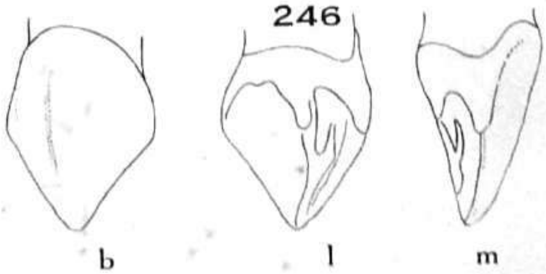

EXPLANATION OF
PLATE XXVI

PLATE XXVI

Figure 247. *Sinanthropus* 2. I^1 rt, p.

Figure 248. Recent Man (prehistoric Chinese No. 157). I^1 rt, p.

Figure 249. *Sinanthropus* 1. I^1 lt, p.

Figure 250. *Sinanthropus* 6. I^2 rt; b, m, d.

Figure 251. Left: *Sinanthropus* 6, I^2 rt; p. Right: Recent North Chinese I^2 rt; p.

Figure 252. *Sinanthropus* mandible B I with c (*121*), I_2 (61), I_1 (*54*), I_2 (*62*), c (*122*). b buccal and l lingual view.

Figure 253. *Sinanthropus* 8. I_2 lt: b, l, m, d.

Figure 254. *Sinanthropus* *68*. C′, lt, l.

Figure 255. *Sinanthropus* 14. C′ rt; b, m, d.

Figure 256. *Sinanthropus* 13. C′ lt; l; p.

Weidenreich—Sinanthropus teeth

Plate XXVI, figs. 247-256

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b m d

251

p p

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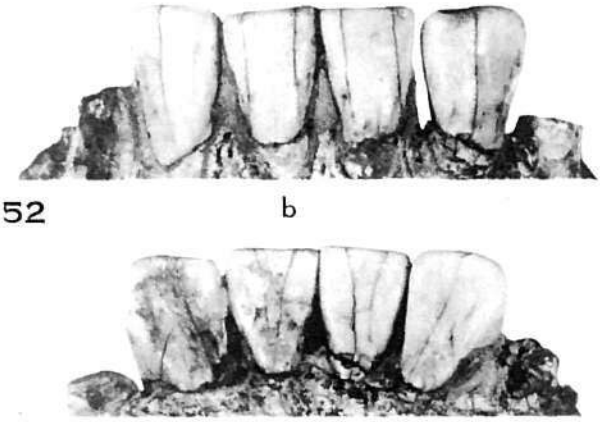

b

l

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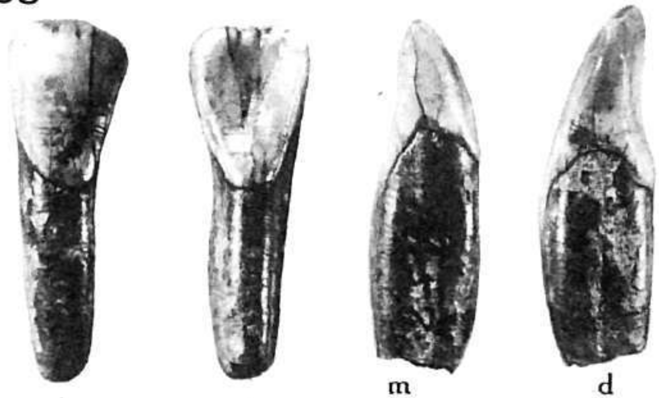

b l m d

254

l

255

b m d

256

l p

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PLATE XXVII

Figure 257. *Sinanthropus* 16. C′ rt; b, m, d.

Figure 258. Fossil orang ♀ (Yünnan). C, rt; m, d.

Figure 259. *Sinanthropus* ♂ *68* C′ rt, b, and *Sinanthropus* ♂ *77* P^1 lt. b=mirror image.

Figure 260. *Sinanthropus* 16. C′ rt, b, and *Sinanthropus* 19, P^1 rt, *b*.

Figure 261. *Sinanthropus 70* C, lt; l.

Figure 262. *Sinanthropus* ♀ *69*. C′ lt, b, and *Sinanthropus* ♀ *78*. P^1 rt, b, (mirror image).

Figure 263. Left *Sinanthropus* ♀ *69*. C′ lt, m; right: *Sinanthropus* ♂ *68*. C′ lt, d.

Figure 264. Left: *Sinanthropus* ♀ *78*. P^1 rt, d; right: *Sinanthropus* ♂ *77*. P^1 lt, m.

Figure 265. *Sinanthropus* mandible B V. C, lt (*72*), I_2 lt (*64*), I_1 lt (*58*), I_1 rt (57), I_2 rt (65), C, rt (*71*), P_1 rt (*81*). a, occlusal view, b, buccal view.

Weidenreich—Sinanthropus teeth

Plate XXVII, figs. 257-265

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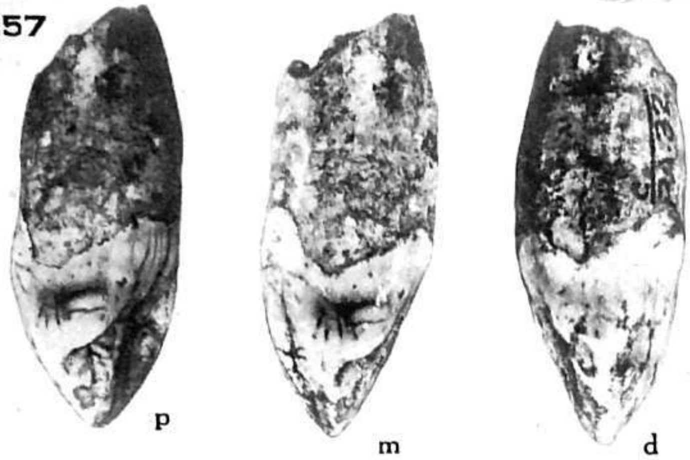

p m d

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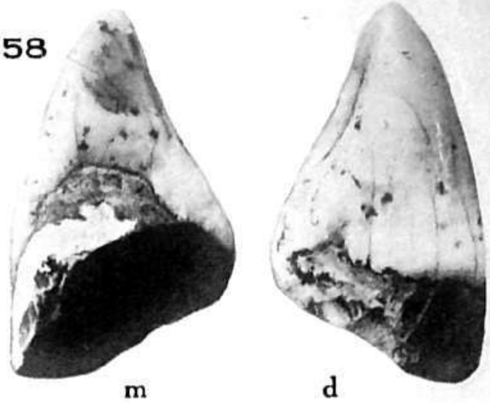

m d

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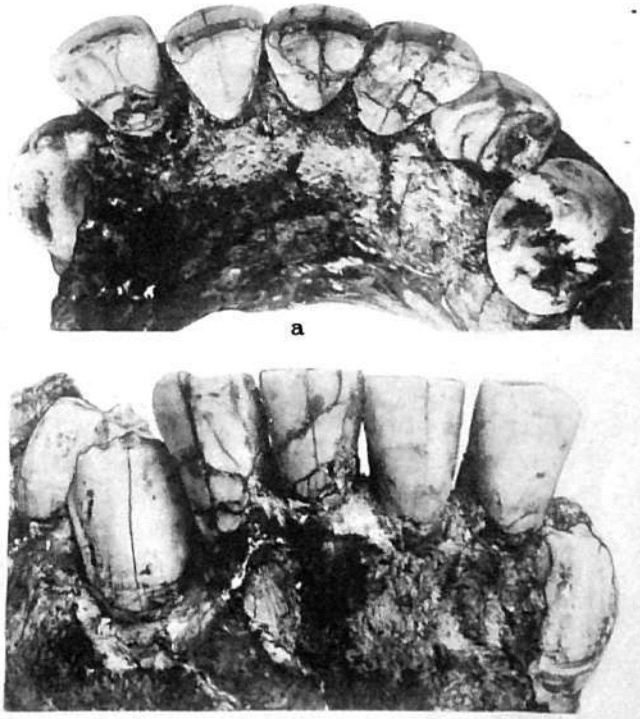

a

b

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EXPLANATION OF PLATE XXVIII

PLATE XXVIII

Figure 266. *Sinanthropus* mandible B V viewed from the left side: C, lt (*72*), I_2 lt (64), P_1 rt (*81*).

Figure 267. *Sinanthropus* 19. P^1 rt; m, o.

Figure 268. *Sinanthropus 77.* P^1 lt, o.

Figure 269. *Sinanthropus* 27. P^2 lt, d, o.

Figure 270. *Sinanthropus* 20. P_1 rt; b, l, m, d, o.

Figure 271. *Sinanthropus* 29. P_2 rt; b, l, m, d.

Figure 272. P_1 rt: a, chimpanzee ♂ adult; b, *Sinanthropus 80* (mandible B I), germ; c, *Sinanthropus* 20, germ; d, germ of recent man (prehistoric Chinese); e, germ of recent man (European, Moravian); f, recent man, adult (European).

Figure 273. P_2 rt: a, germ of chimpanzee (Cat. No. 321); b, *Sinanthropus 89* (mandible B I), germ; c, *Sinanthropus 90* (mandible B V), germ; d, *Sinanthropus* 29, germ; e, germ of recent man (prehistoric Chinese); f, recent man, adult (European).

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m

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268

o

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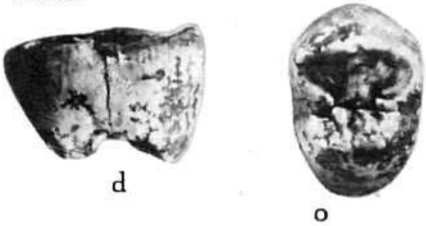

d o

270

b l m d o

271

b l m d o

272

a b c d e f

273

a b c d e f

EXPLANATION OF PLATE XXIX

PLATE XXIX

Figure 274. *Sinanthropus* mandible B I in occlusal view with germ of P_2 rt (*89*)—cf. figure 273—exposed and *in situ*. 1/1.

Figure 275. *Sinanthropus* 41. M^2 lt, o.

Figure 276. *Sinanthropus* 32. M^1 rt, o.

Figure 277. *Sinanthropus* upper jaw of Skull II Locus L; left side in occlusal view with P^1 (79), P^2 (*88*), M^1 (95), M^2 (*105*), M^3 (*113*). 1/1.

Figure 278. *Sinanthropus* 40. M^2 lt, o.

Figure 279. *Sinanthropus* 46. M^3 rt; b, l, m, d, o.

Figure 280. *Sinanthropus* 48. M^3 rt, o.

Figure 281. *Sinanthropus* 47. M^3 lt, o.

Figure 282. Fossil orang (Kwangsi). M^3 rt; o.

Figure 283 *Sinanthropus* mandible G I, left side in occlusal view with I_1 (59), I_2 (*66*), C (*73*), P_1 (*83*), P_2 (*91*), M_1 (*100*), M_2 (*110*), M_3 (*116*). 1/1

Figure 284. *Sinanthropus* mandible A II right side in occlusal view with M_1 (*96*), M_2 (*106*), M_3 (*114*). 1/1

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PLATE XXX

Figure 285. *Sinanthropus* mandible G I left side in buccal view with the same teeth as in figure 283. 1/1.

Figure 286. *Sinanthropus 99*. M$_1$ rt and *108*. M$_2$ rt, of mandible F I.

Figure 287. *Sinanthropus* mandible K I left side in buccal view, with C (*75*), P$_1$ (*85*), P$_2$ (*93*), M$_1$ (*102*), M$_2$ (*111*). 1/1.

Figure 288. The same as in figure 287 in occlusal view. 1/1.

Figure 289. *Sinanthropus* M$_1$ (*96*), M$_2$ (106), M$_3$ (114) *in situ*. Mandible A II (figure 264) viewed from the lingual side from behind and above. 1/1.

Figure 290. *Sinanthropus* 44. M$_2$ lt, o.

Figure 291. Chimpanzee M$_1$ rt (Cat. No. 381), o.

Figure 292. Orang M$_1$ rt (Cat. No. 371), o.

Figure 293. Recent Man (Japanese child), M$_1$ rt, o.

Figure 294. *Sinanthropus* 36, M$_1$ lt; b, l, m. d. o.

Figure 295. *Sinanthropus* 50, M$_3$ lt, o.

Figure 296. *Sinanthropus* 52, M$_3$ rt, o.

Figure 297. Gorilla ♂ (Cat. No. 329) P$_1$-M$_3$ *in situ*. 1/1.

PALÆONTOLOGIA SINICA

Weidenreich—Sinanthropus teeth

Plate XXX, figs. 285-297

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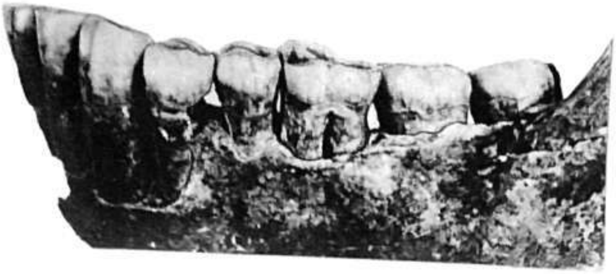

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EXPLANATION OF

PLATE XXXI

PLATE XXXI

Figure 298. Upper jaw of gorilla ♂ (Cat. No. 333) with P^1-M^3 on both sides *in situ*. 1/1.

Figure 299. *Sinanthropus* mandible B IV, right side, with i_1 (*118*), i_2 (*119*), c (*120*), m_1 (*125*), m_2 (*128*). a, buccal view; b, lingual view; c, occlusal view.

Figure 300. Mandible of *Perodicticus potto* with all incisors and the permanent dentition of the right side. Viewed from lingual side and above.

Figure 301. Comparative occlusal view of the dental arches of: a, chimpanzee ♂ (Cat. No. 426). b, *Sinanthropus* ♀ mandible H I (reconstructed), c, Recent Man ♀ (European-Moravian), d, Heidelberg mandible (after Schoetensack). 1/2.

Figure 302. Skiagram of *Sinanthropus* mandible B V (cf. figure 265) to demonstrate the roots of the permanent incisors. 1/1.

Figure 303. Skiagram of *Sinanthropus* mandible B IV (cf. figure 299) to demonstrate the roots of the deciduous teeth. 1/1.

Weidenreich—Sinanthropus teeth

Plate XXXI, figs. 298-303

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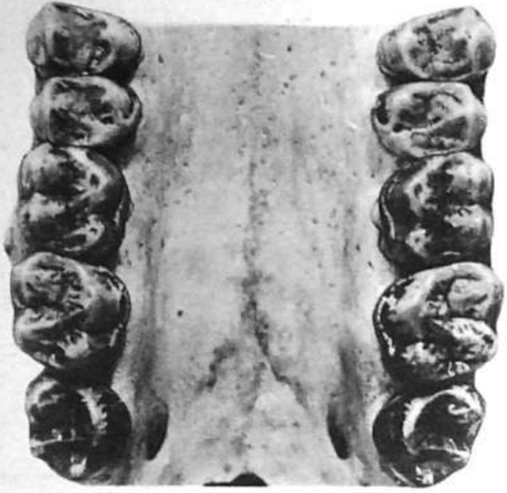

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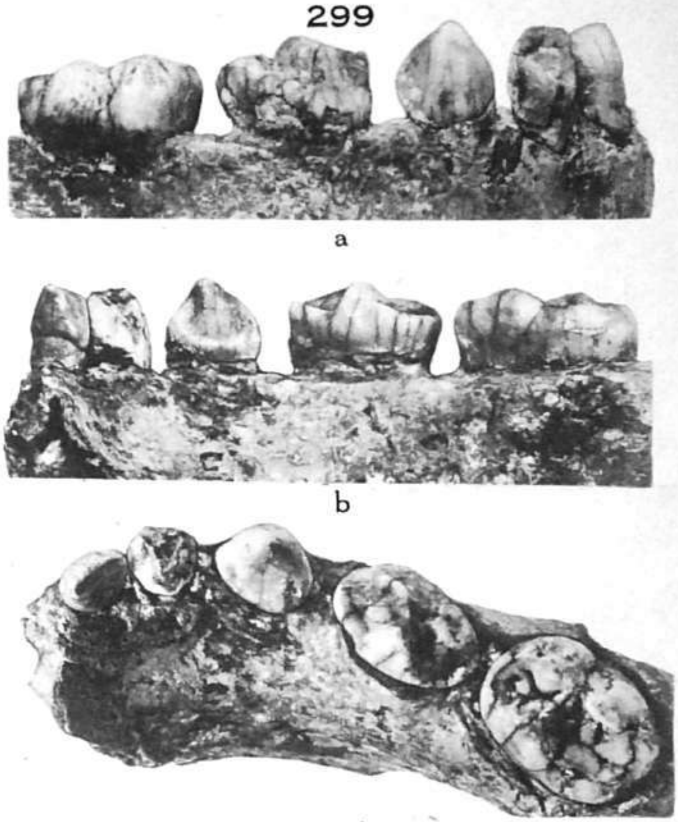

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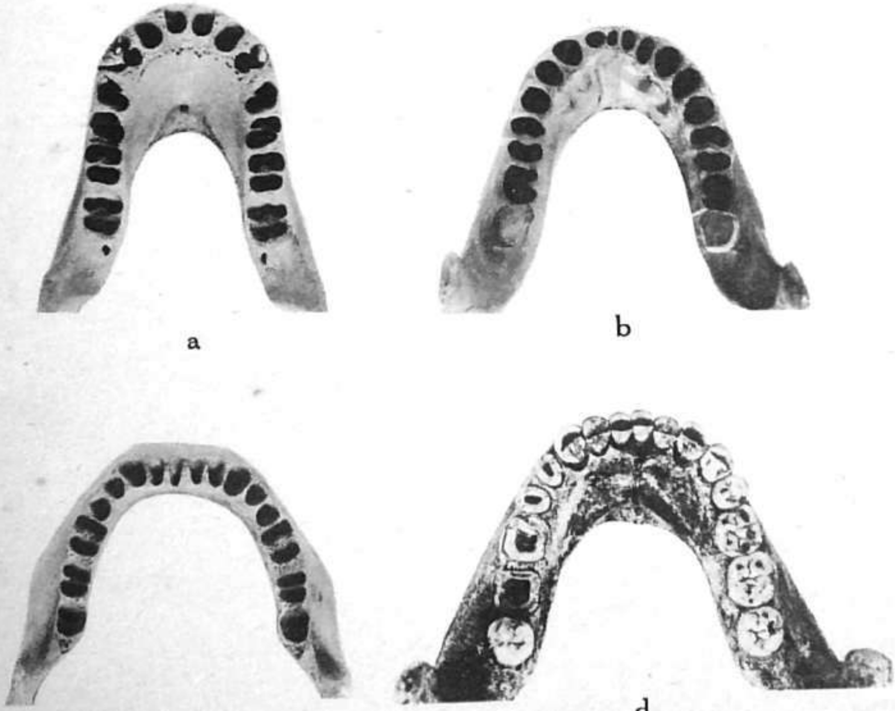

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EXPLANATION OF

PLATE XXXII

PLATE XXXII

Figure 304. Recent Man♀. Prehistoric Chinese (Cat. No. 404/7). Strong alveolar prognathism of maxilla and mandible. Overbite. 1/2.

Figure 305. Recent Man♂ North Chinese (Cat. No. 191). Strong alveolar prognathism. Overbite. 1/2.

Figure 306. Dentition of a female orang (Borneo) with erect upper and lower incisors and edge-to-edge bite. No diastemata. 1/2.

Figure 307. Skiagram of *Sinanthropus* mandible G I (cf. figs. 283 and 285). 1/1.

Figure 308. Skiagram of *Sinanthropus* upper jaw of Skull II Locus L (cf. fig. 277) with P^1-M^3. 1/1.

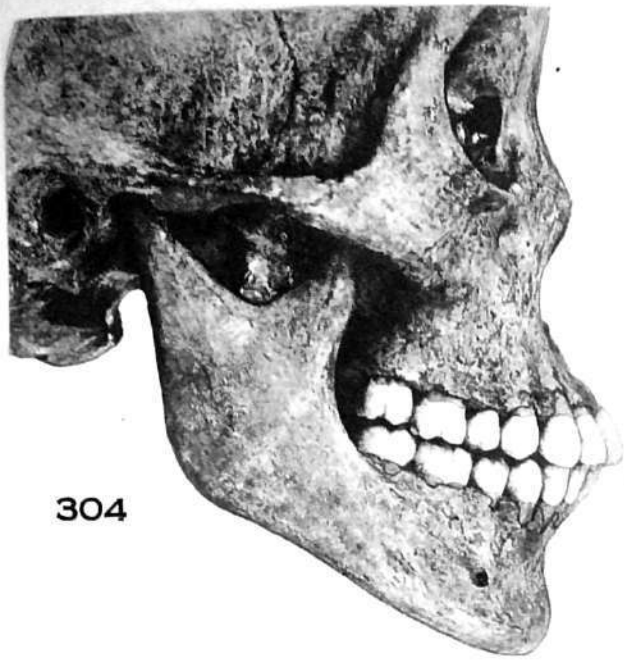
Figure 309. Skiagram of *Sinanthropus* mandible K I (cf. figs. 287 and 288) with C-M_3. 1/1.

Figure 310. Skiagrams (bucco-lingual) of chimpanzee ♂ M_1 lt: a, immature (Cat. No. 421); b. adult (Cat. No. 426). 1/1.

Figure 311. Skiagrams (bucco-lingual) of *Sinanthropus* M_1 lt: a, immature No. 36; b, adult No. 38. 1/1.

Figure 312. Skiagrams (bucco-lingual) of Recent Man (European) M_1 lt: a, immature, b, adult. 1/1.

Figure 313. Skiagrams (mesio-distal) of *Sinanthropus* upper molars of Skull II Locus L: a, M^1 rt, No. *94*; b, M^2 rt, No. *104*. 1/1.



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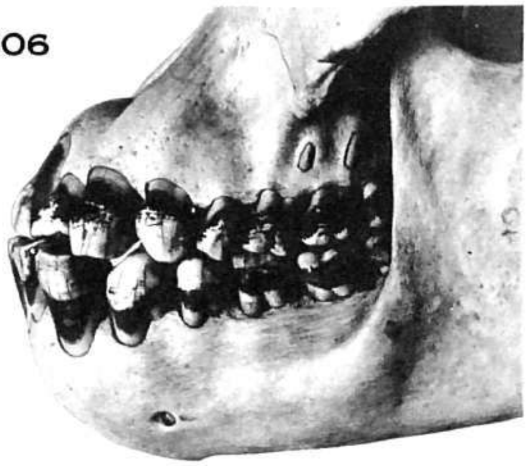

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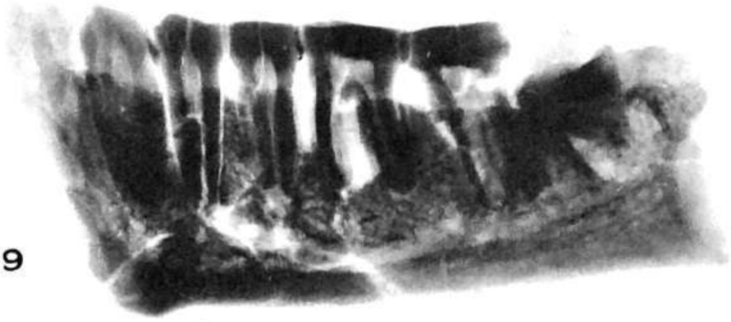

310 ch.

a b

311 S.

a b

312 H.s.

a b

313 S.

a b

EXPLANATION OF

PLATE XXXIII

PLATE XXXIII

Figure 314. Skiagram of *Sinanthropus* mandible A II with M_1-M_3 (cf. figs. 284 and 289). 1/1.

Figure 315. Skiagram of the right side of the Heidelberg mandible with M_1-M_3 after Schoetensack. 1/1.

Figure 316. Skiagram of the male mandible (No. 101) of a palæolithic recent man ("Upper Cave" Choukoutien) with M_1-M_3. 1/1.

Figure 317. Skiagram of the right side of the Piltdown mandible with M_1 and M_2 after Underwood. 1/1.

Figure 318. Skiagram of the right side of the mandible of a female gorilla (Cat. No. 112) with M_1 and M_3. 1/1.

Figure 319. Skiagram of the left side of a mandible of a female Eskimo (ancient grave of unknown age) with M_1-M_3. 1/1.

Figure 320. Skiagram of the right side of a female orang (Borneo, cf. fig. 306) with M_1-M_3. 1/1.

Figure 321. Skiagram of the right side of a female orang (Cat. No. 247) with M_1-M_3. 1/1.

Figure 322. Skiagram of the left side of a recent Australian Aboriginal (Cat. No. 14) with M_1-M_3. 1/1.

Figure 323. Skiagram of the left side of the Wadjak mandible II with M_1-M_3. By courtesy of Mr. G. Pinkley. 1/1.

Figure 324. Skiagram of the left side of the mandible of recent man♂ (North Chinese) with P_1-M_3. 1/1.

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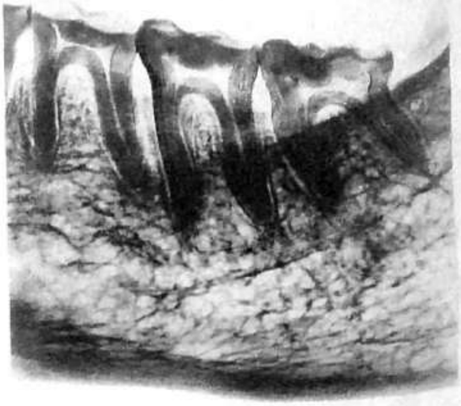

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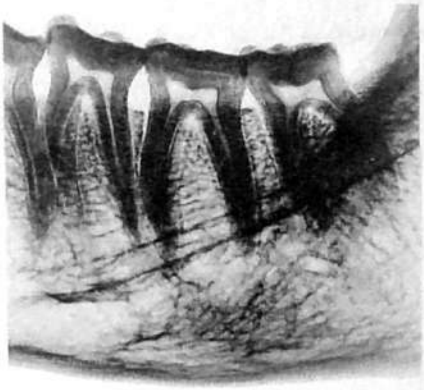

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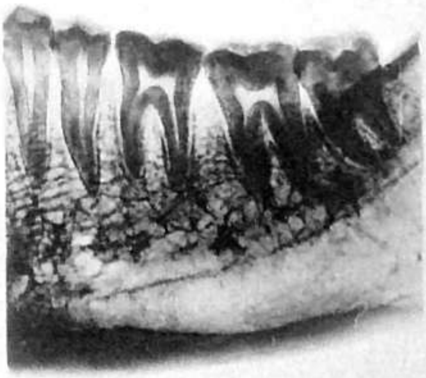

EXPLANATION OF PLATE XXXIV

PLATE XXXIV

Figure 325. Roots of P^1 rt viewed from the apical side to demonstrate the arrangement of the single branches: a, *Sinanthropus* 19 (fig. 64); b, gorilla ♂ (Cat. No. 329).

Figure 326. P^1 and P^2 rt of *Dryopithecus punjabicus* after Pilgrim-Gregory. 1/1.

Figure 327. *Sinanthropus* 133′ P^2 lt, o.

Figure 328. *Sinanthropus* 130′ P_1 rt; b, l, m, d, o.

Figure 329. Outline of P_1 viewed from the occlusal surface to demonstrate the oblique course of its main axis. a, *Sinanthropus 80* P_1 rt (fig. 79); b, *Sinanthropus* Zdansky's P_1 lt (fig. 84); c, *Sinanthropus 85* P_1 lt (fig. 86); d, Krapina P_1 rt (fig. 93); e, Recent Man, after Lenhossek, P_1 rt (fig. 85); f, gorilla ♀ P_1 rt (Cat. No. 333).

Figure 330. *Sinanthropus* 140′ M^1 lt; b, l, m, d, o.

Figure 331. Gorilla ♂ juv. (Cat. No. 336) M^1 rt, viewed from the lingual and mesial side and from above. Abbreviations: prc = protocone; hc = hypocone; pc = paracone; mc = metacone.

Figure 332. Fossil orang (Yünnan) M^1 or M^2 lt, o.

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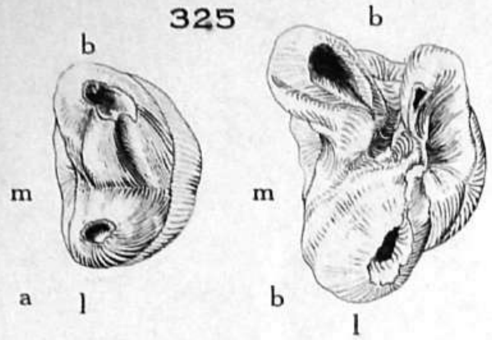

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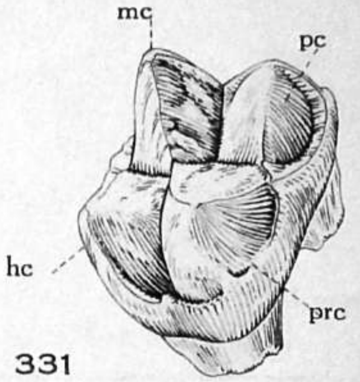

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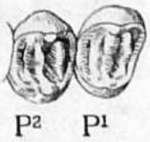

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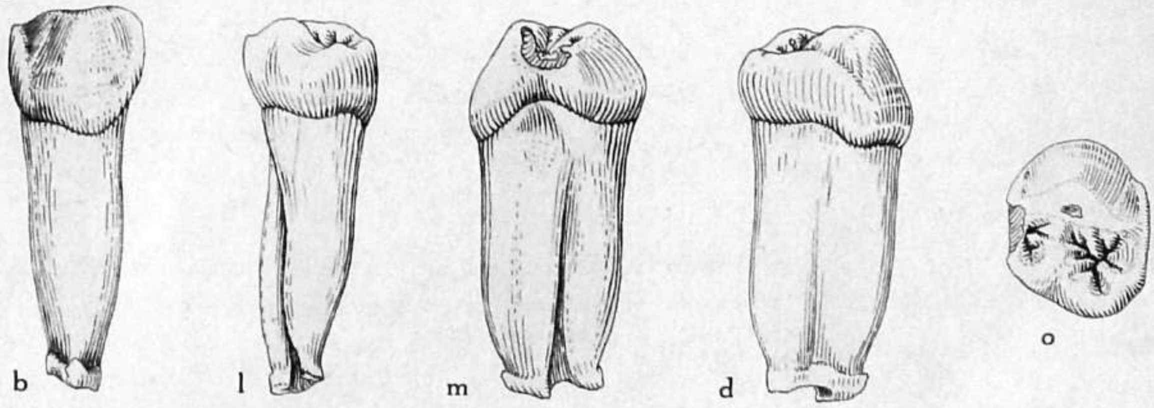

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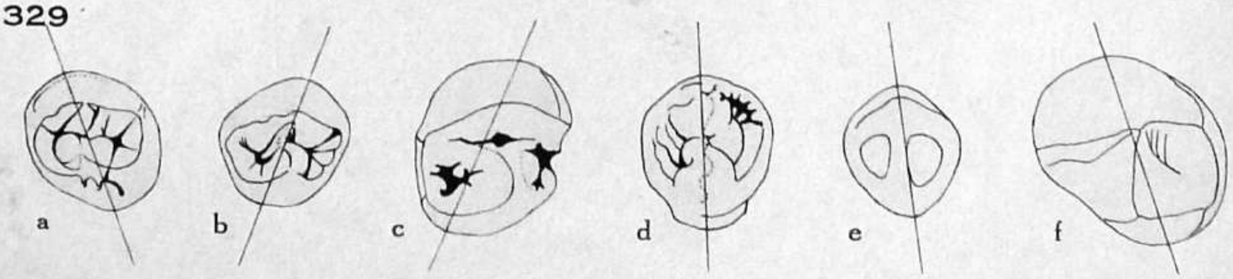

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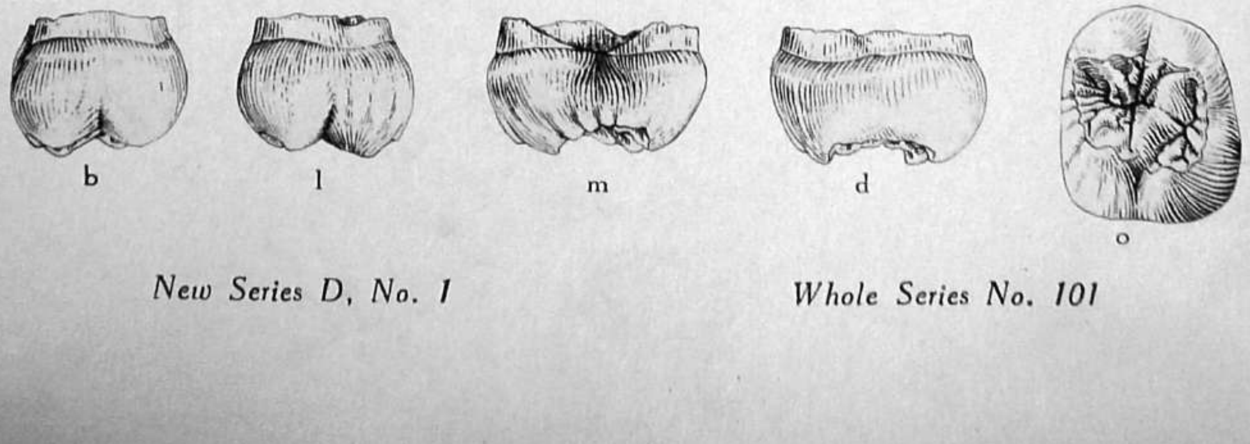


EXPLANATION OF PLATE XXXV

PLATE XXXV

Figure 333. La Quina M^2 lt with root after H. Martin; d.

Figure 334. Carabelli cusps. Recent Man♂ (North Chinese, Cat. No. 189). M^1 lt. a, from lingual side and above; b, occlusal view.

Figure 335. *Dryopithecus darwini* Abel. Left upper molar with Carabelli pit (after Glaessner).

Figure 336. Fossil orang (Yünnan). Right upper molar. a, occlusal view; b, Carabelli pit viewed from mesial and lingual side.

Figure 337. *Cebus capucinus.* M^3 lt. Accessory interior cusp between protocone and hypocone.

Figure 338. *Lemur rufifrons* (Cat. No. 174) M^1 and M^2 lt with accessory interior cusps.

Figure 339. *Sinanthropus* 137′. M_1 lt; b, d, o.

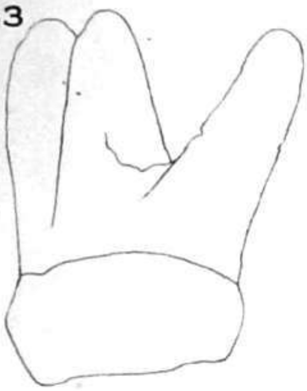
Figure 340. *Sinanthropus* 131′ M_2 rt; b, l, o.

Figure 341. *Sinanthropus* mandible B III. m_1 rt, No. *124*. Crown broken off. Root viewed from above.

Figure 342. Female orang. M_1 and M_2 rt in occlusal view after Selenka to demonstrate the manner of attrition.

Plate XXXV, figs. 333-342

333



d

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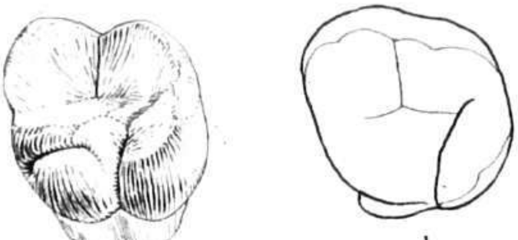

a

b

335

d

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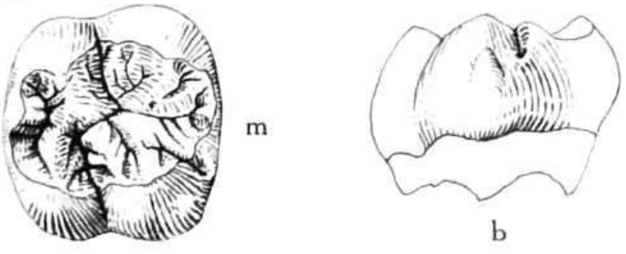

a

b

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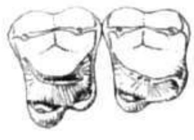

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b

d

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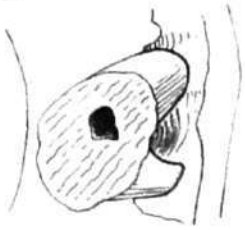

340

b

l

o

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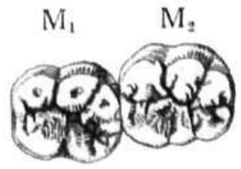


EXPLANATION OF

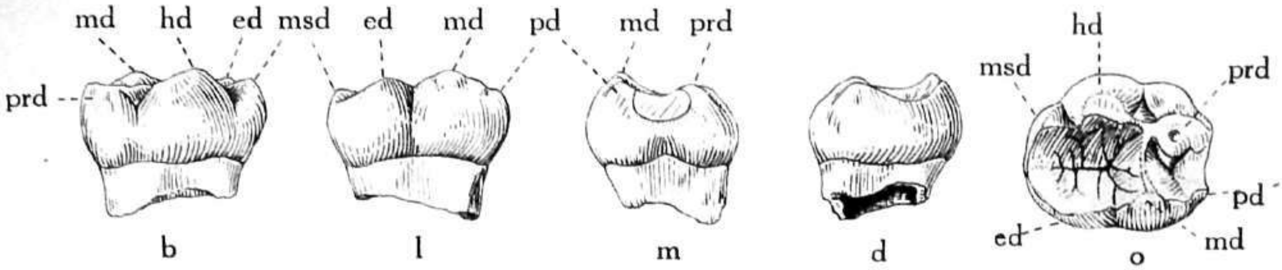
PLATE XXXVI

PLATE XXXVI

Figure 343. *Sinanthropus* 139′ m_2 lt; b. l. m. d. o. Abbreviations: ed = entoconid; hd = hypoconid; md = metaconid; msd = mesoconid; pd = paraconid; prd = protoconid.

Figure 344. Second deciduous molar in buccal (above) and occlusal (below) view of *Sinanthropus* 139′ (b), *Dryopithecus rhenanus* (c), chimpanzee (d), recent American Indian (e), compared with a permanent molar of an Eocene Tarsioid-Omomys—(a). All figures, with the exception of that of *Sinanthropus* (b) after Gregory (1922). (a) x 3/1; the remaining figures x 3/2.

Figure 345. *Sinanthropus* left upper jaw of Locus O I. Lateral view. I^1 and C' restored after original *Sinanthropus* specimens. 1/1.



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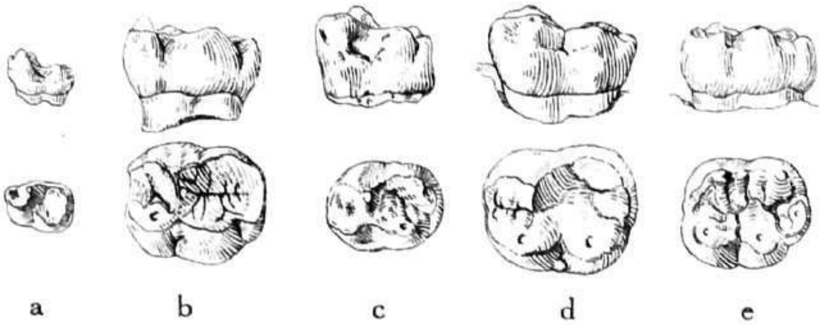

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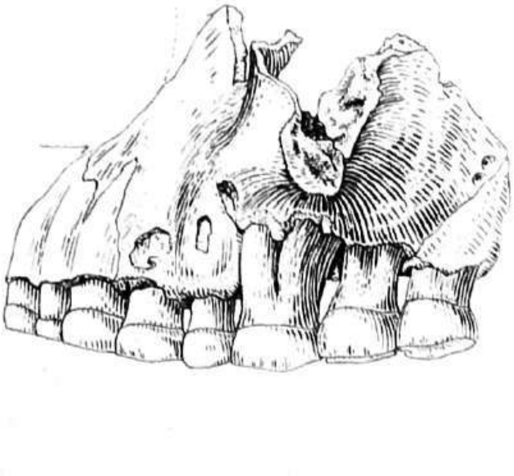

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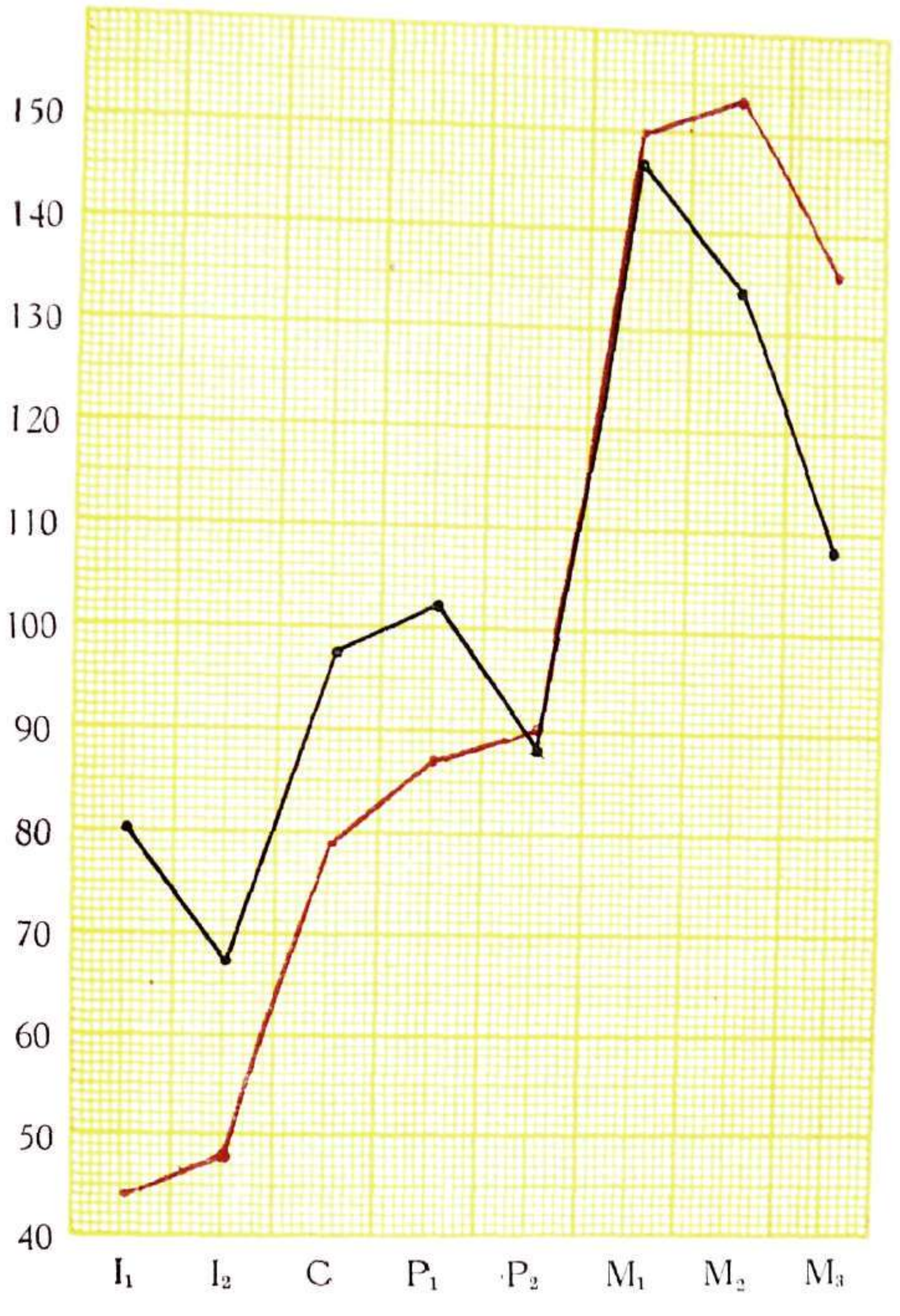

Diagram 1. Robustness of the crowns of *Sinanthropus* teeth. Upper teeth in black; lower teeth in red.

Diagram 2. Robustness of the crowns of the *Sinanthropus* upper teeth (black) compared with that of recent man (red) and Neanderthal man (red interrupted line).

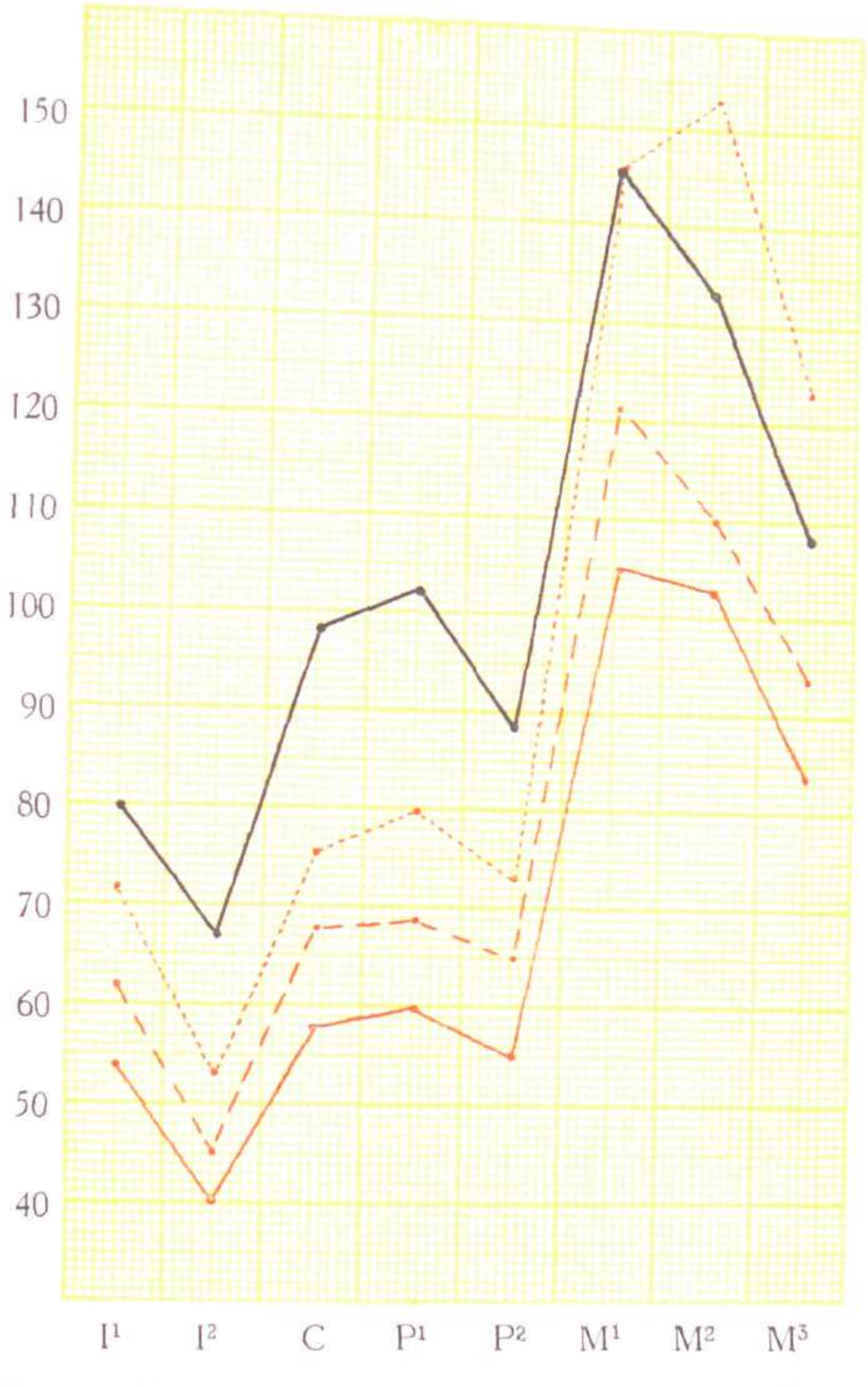

Diagram 3. The same as Diagr. 2 compared with that of Australian Aboriginal (red dotted line), Japanese (red interrupted line) and Bushman (red full line).

Diagram 4. Robustness of the crowns of the *Sinanthropus* lower teeth (black) compared with that of recent man (red) and Neanderthal man (red interrupted line).

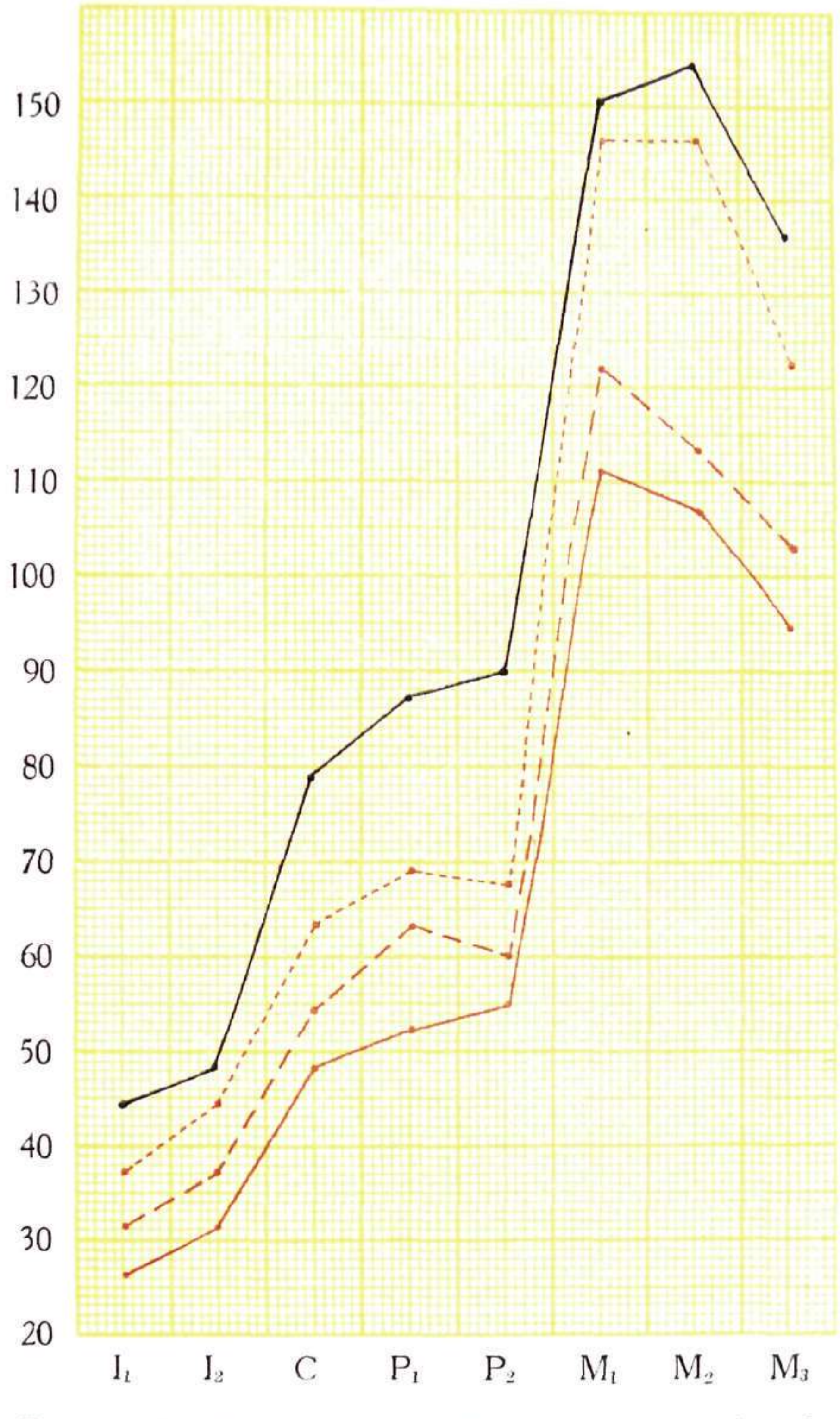

Diagram 5. The same as Diagr. 4 compared with Australian Aboriginal (red dotted line), Japanese (red interrupted line) and Bushman (red full line).

Diagram 6. Robustness of the crowns of the lower teeth of *Sinanthropus* (black) and the Heidelberg mandible (red).

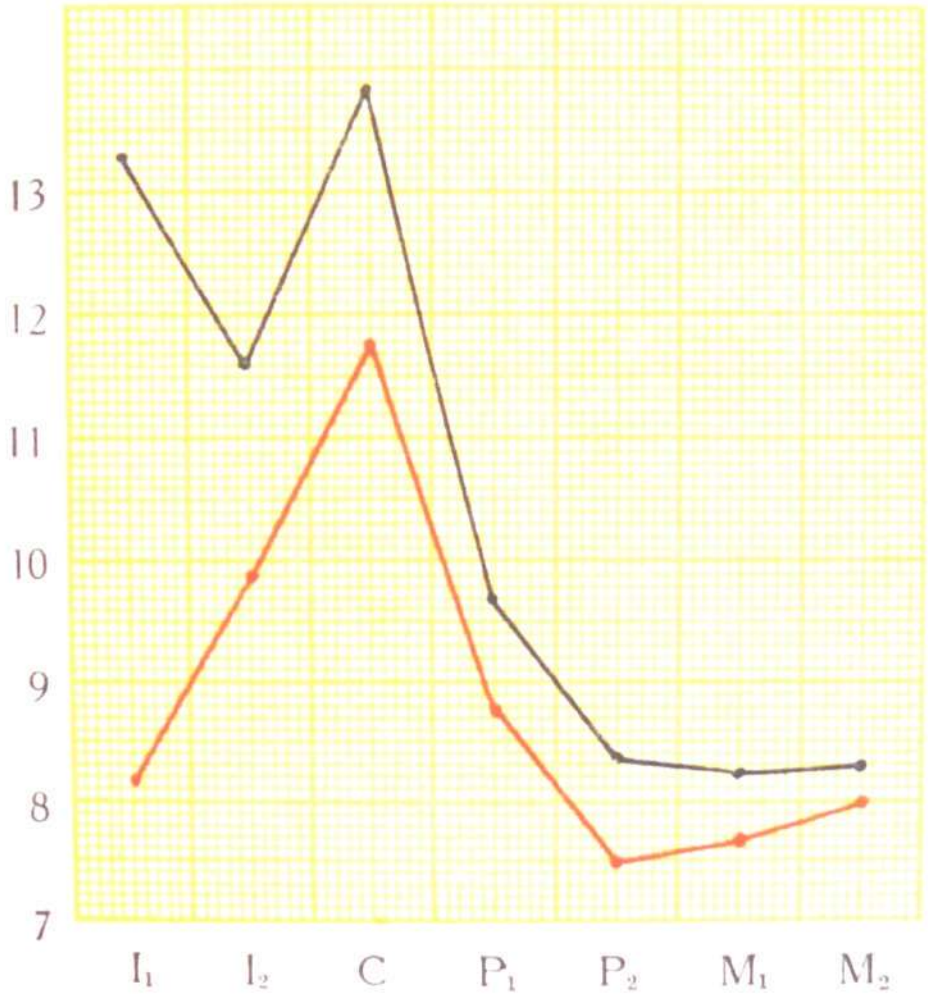

Diagram 7. Height of the crowns of the *Sinanthropus* teeth. Upper teeth: black; lower teeth: red.

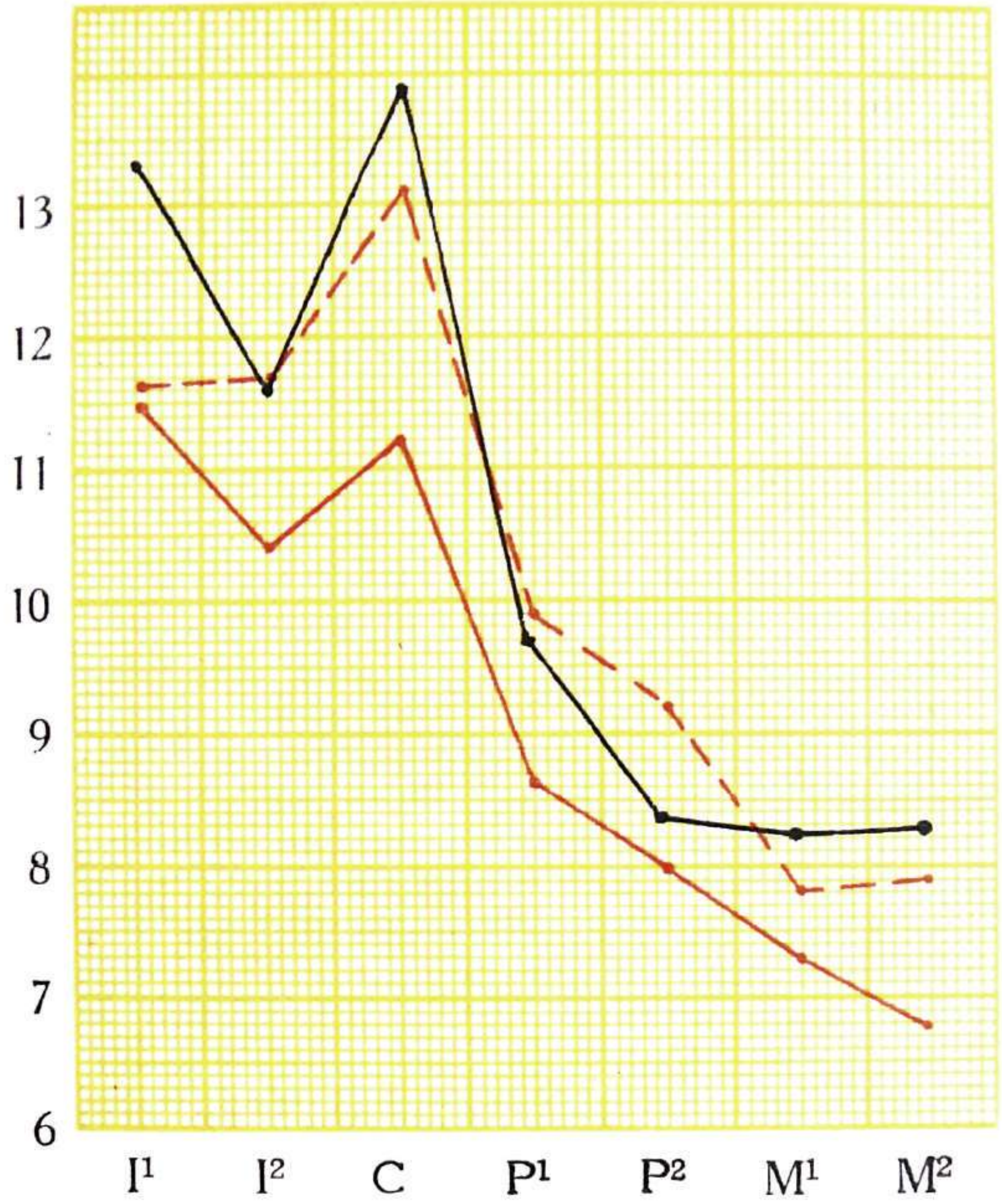

Diagram 8. Height of the crowns of the *Sinanthropus* upper teeth (black) compared with that of recent man (red) and Neanderthal man (red interrupted line).

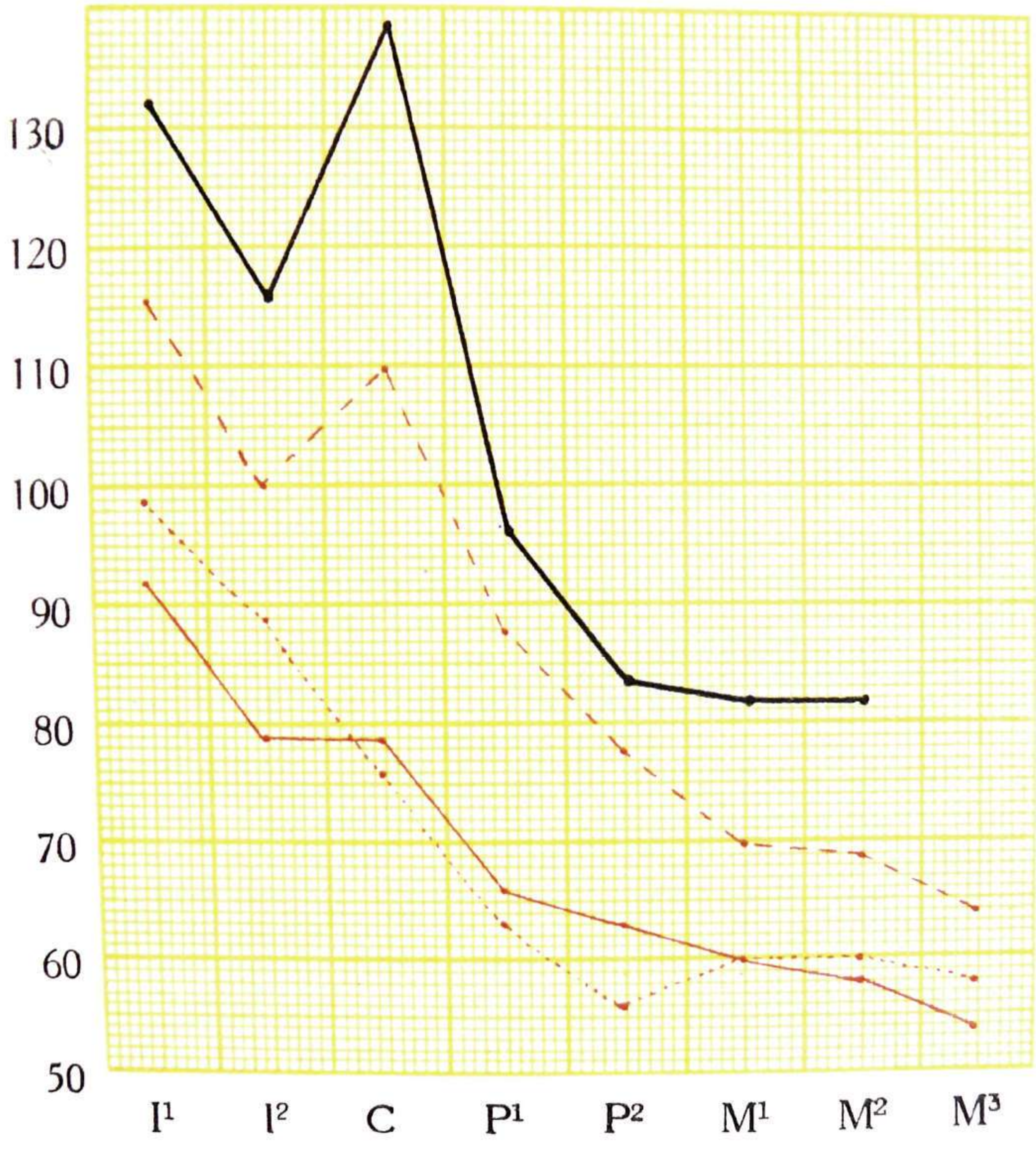

Diagram 9. The same as Diagr. 8 compared with Australian Aboriginal (red dotted line), Japanese (red interrupted line) and Bushman (red full line).

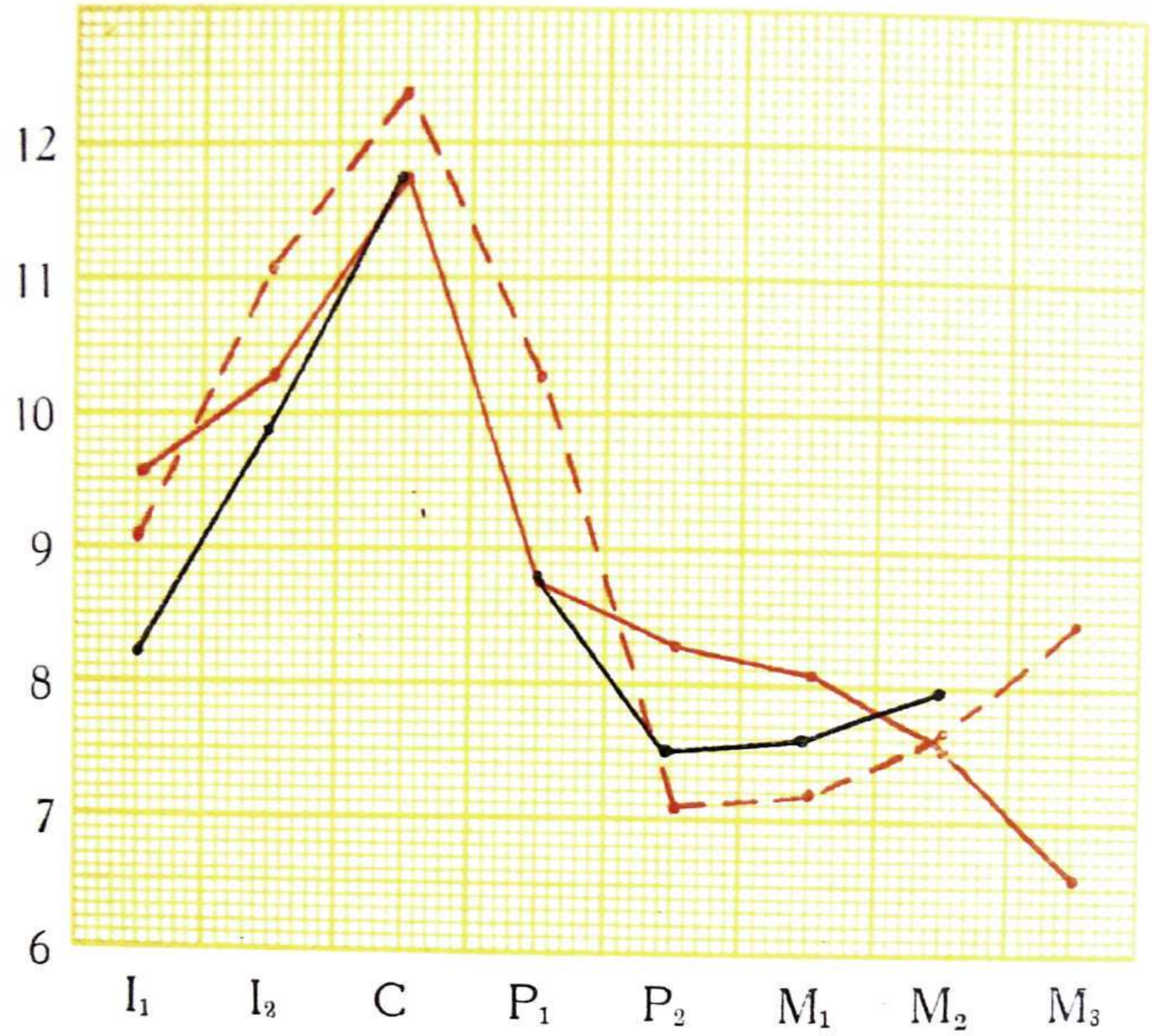

Diagram 10. Height of the crowns of the *Sinanthropus* lower teeth (black) compared with those of recent man (red) and Neanderthal man (red interrupted line).

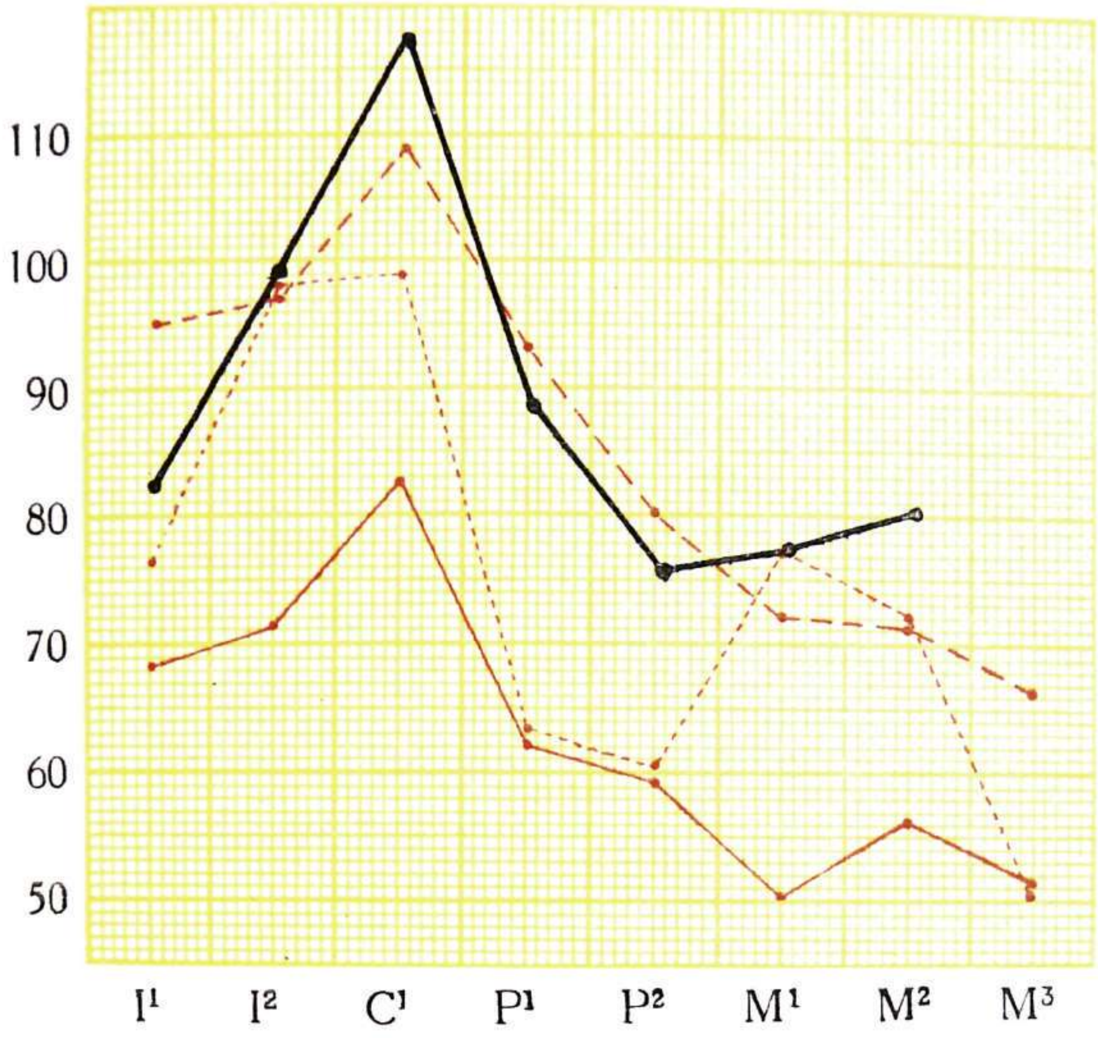

Diagram 11. The same as Diagr. 10 compared with Australian Aboriginal (red dotted line), Japanese (red interrupted line) and Bushman (red full line).

Diagram 12. Robustness of the roots of the *Sinanthropus* teeth. Upper teeth: black; lower teeth: red.

Diagram 13. Robustness of the roots of the *Sinanthropus* upper teeth (black) and that of recent man (red).

Diagram 14. Robustness of the roots of the *Sinanthropus* lower teeth (black) and recent man (red).

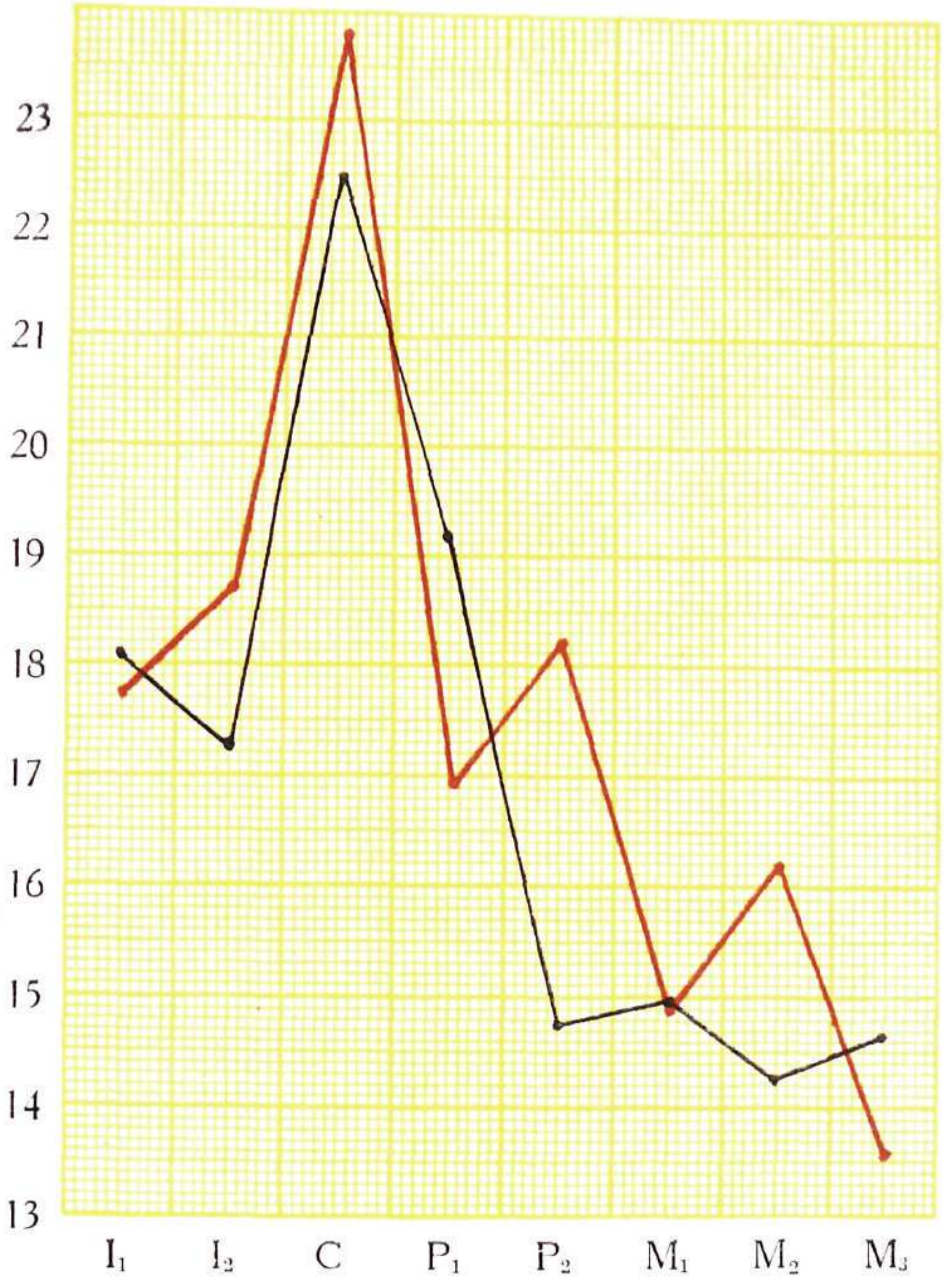

Diagram 15. Height of the roots of the *Sinanthropus* teeth. Upper teeth: black; lower teeth: red.

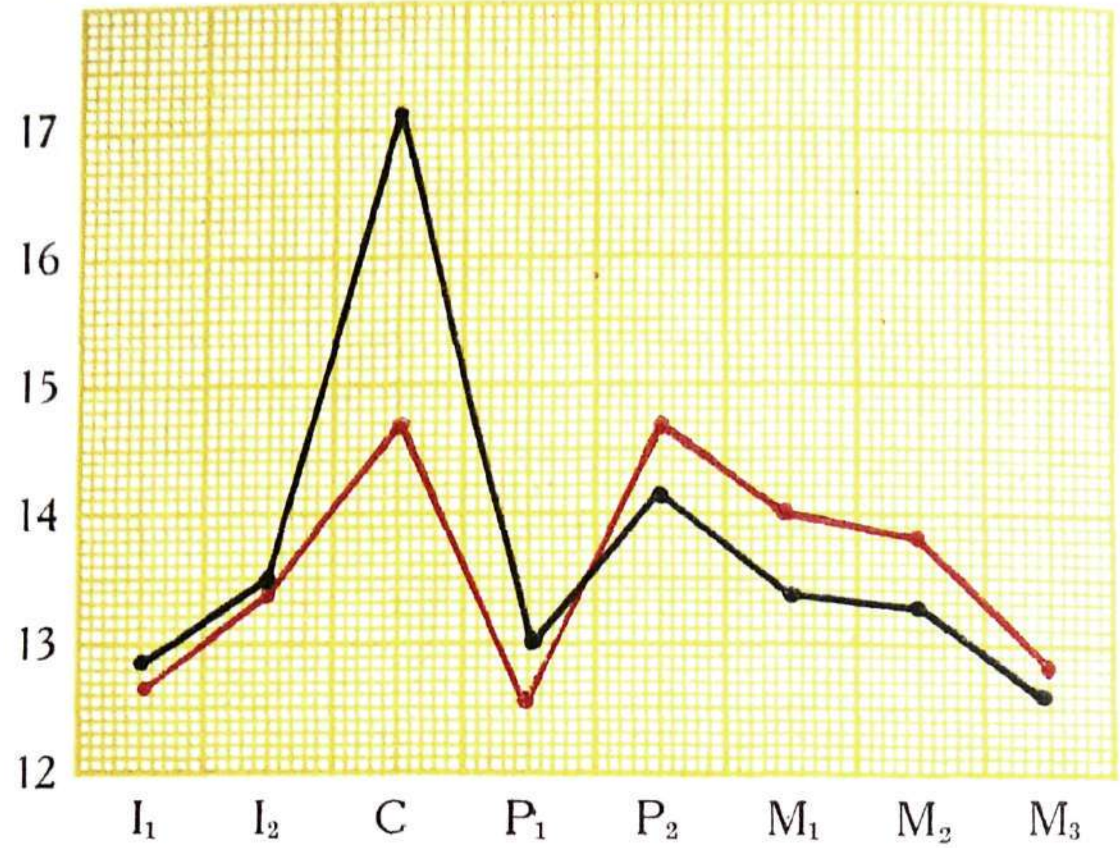

Diagram 16. Height of the roots of the teeth of recent man. Upper teeth: black; lower teeth: red.

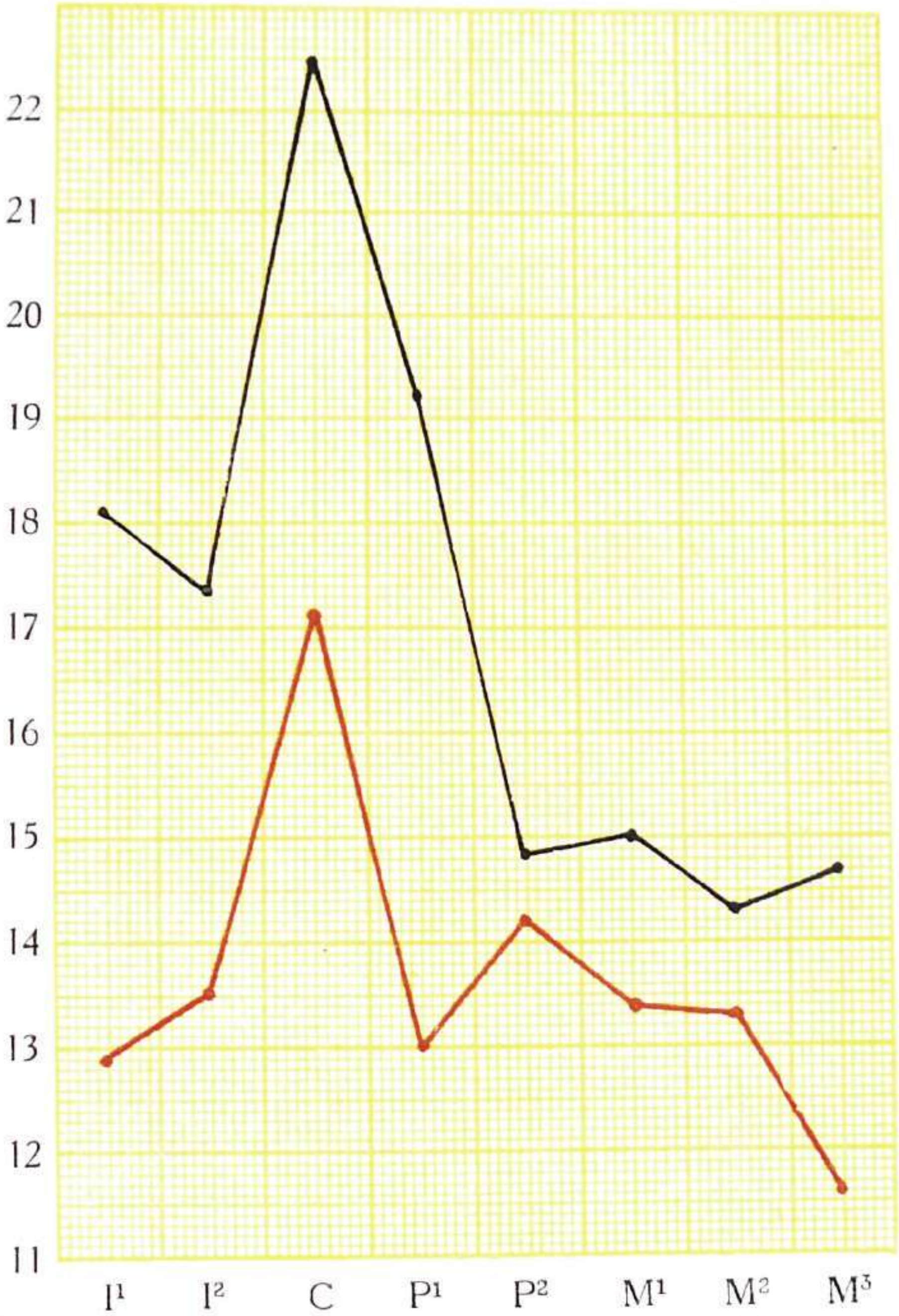

Diagram 17. Height of the roots of the *Sinanthropus* upper teeth (black) and that of recent man (red).

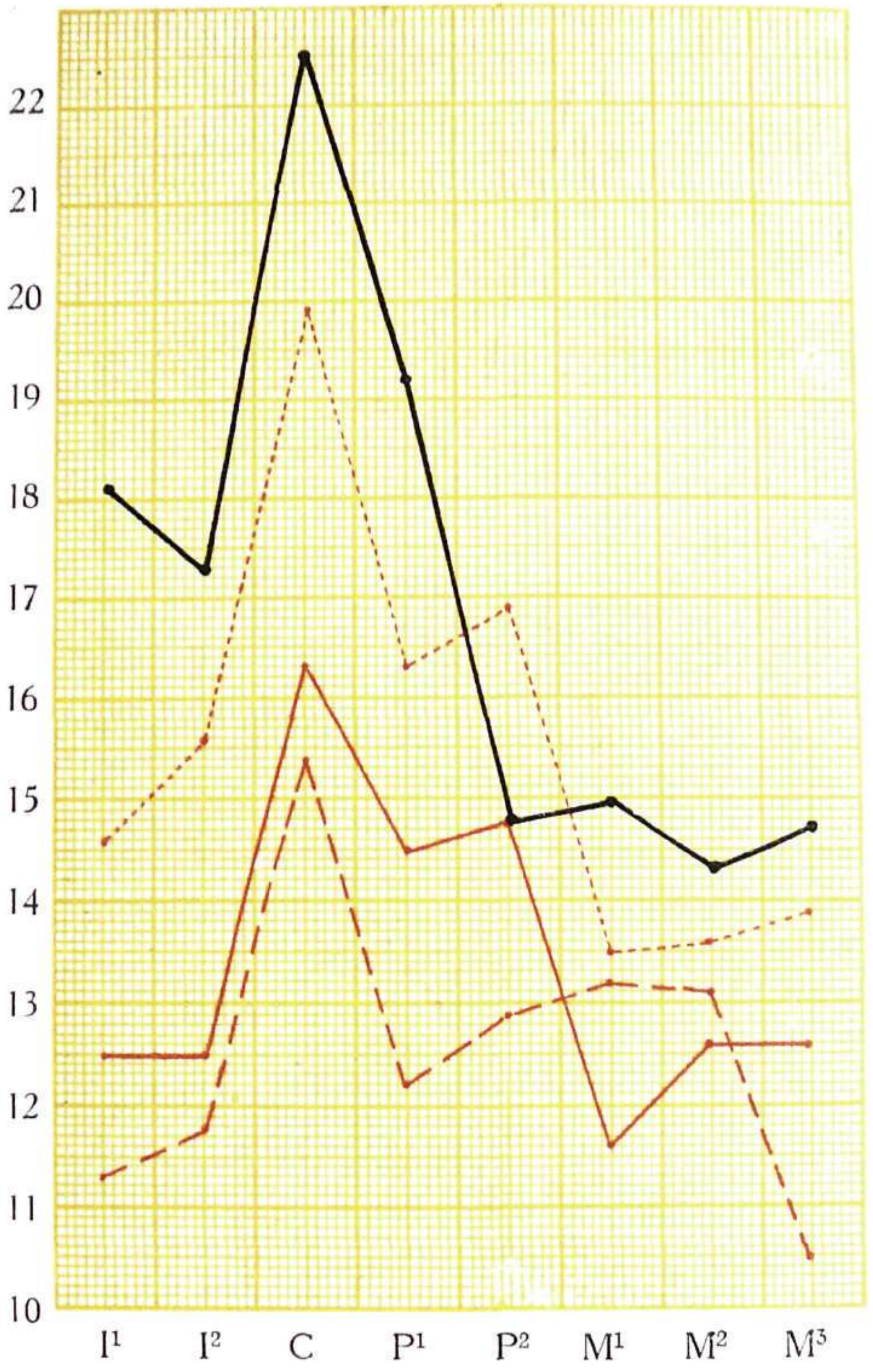

Diagram 18. The same as Diagr. 17, compared with Australian Aboriginal (red dotted line), Japanese (red interrupted line) and Bushman (red full line).

Diagram 19. Height of the roots of the *Sinanthropus* lower teeth (black) and that of recent man (red).

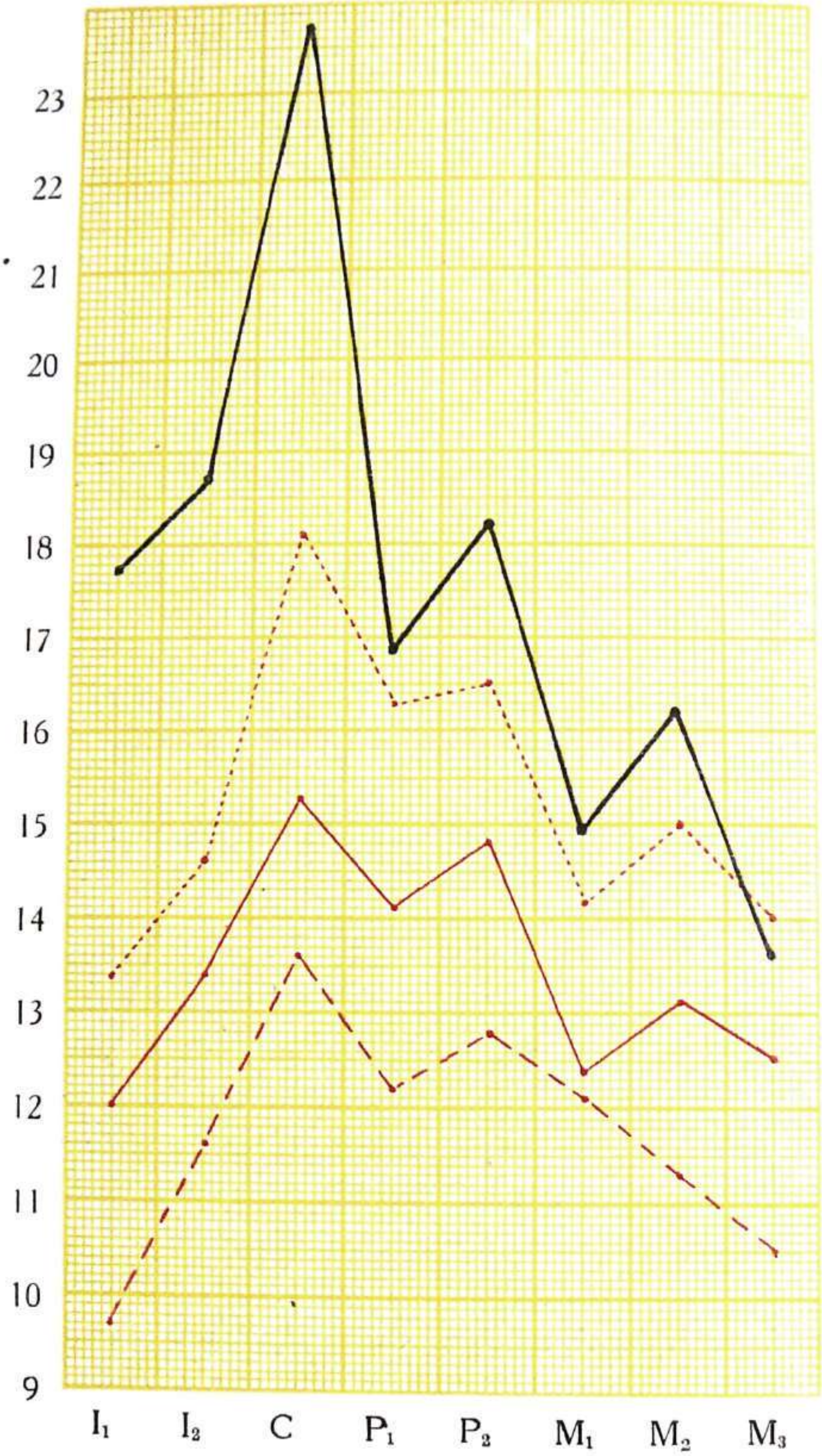

Diagram 20. The same as Diagr. 19, compared with Australian Aboriginal (red dotted line), Japanese (red interrupted line) and Bushman (red full line).

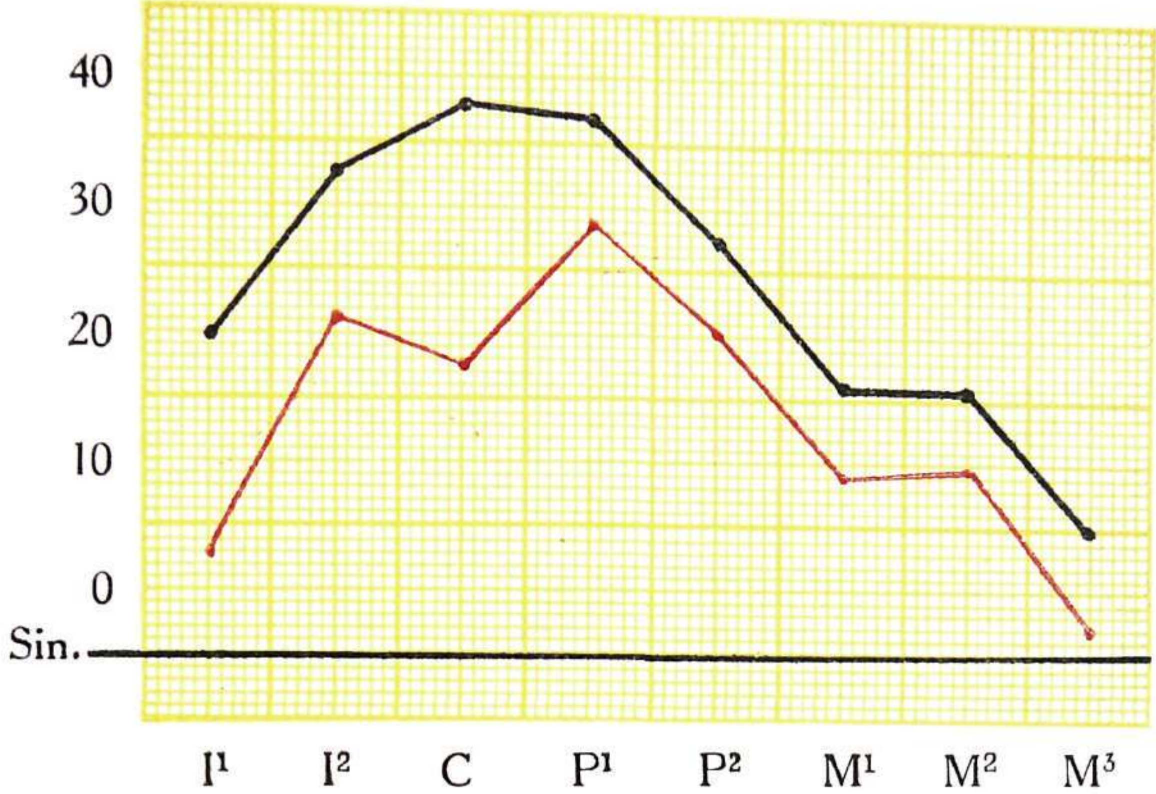

Diagram 21. Decrease of the robustness of the crowns (red) and roots (black) of the upper teeth of recent man expressed in percentage of the respective values for the *Sinanthropus* teeth.

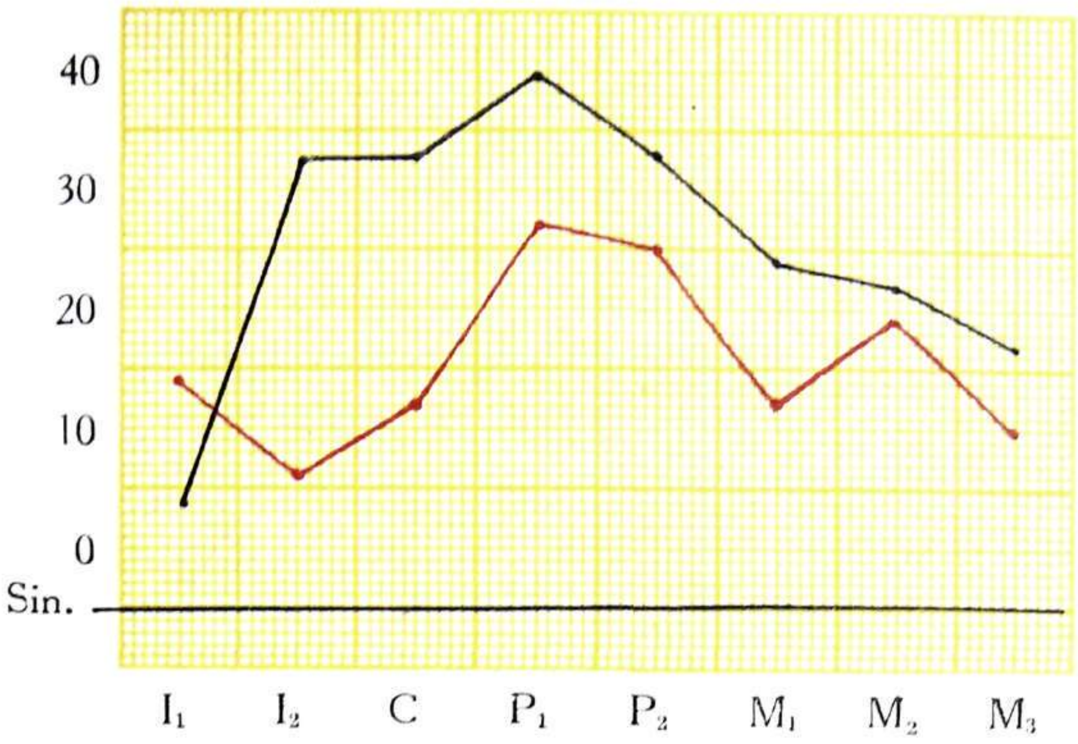

Diagram 22. The same as Diagr. 21 for the lower teeth.

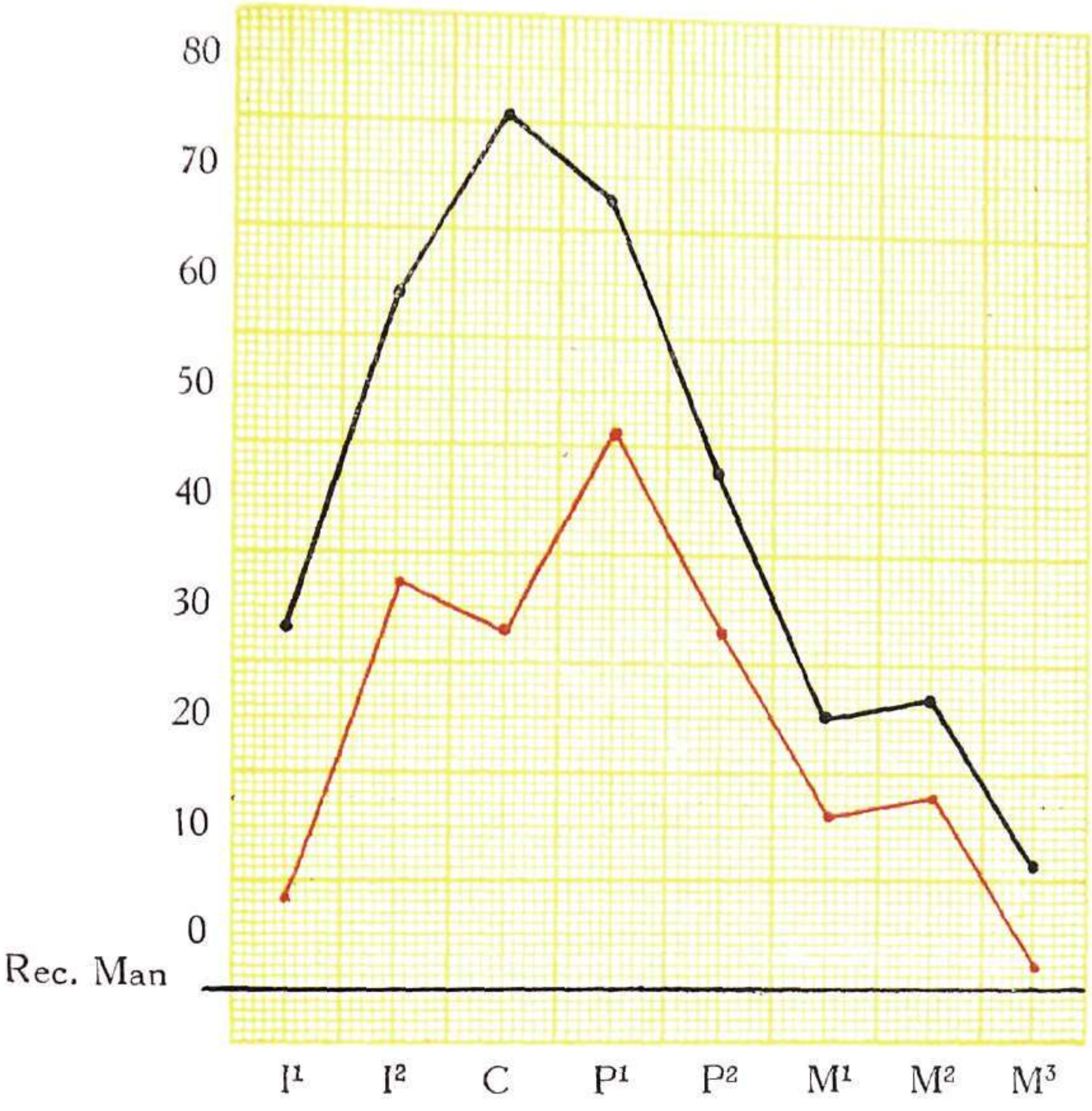

Diagram 23. Predominance of robustness of the crowns (red) and roots (black) of the upper teeth of *Sinanthropus* expressed in percentage of the respective values for recent man.

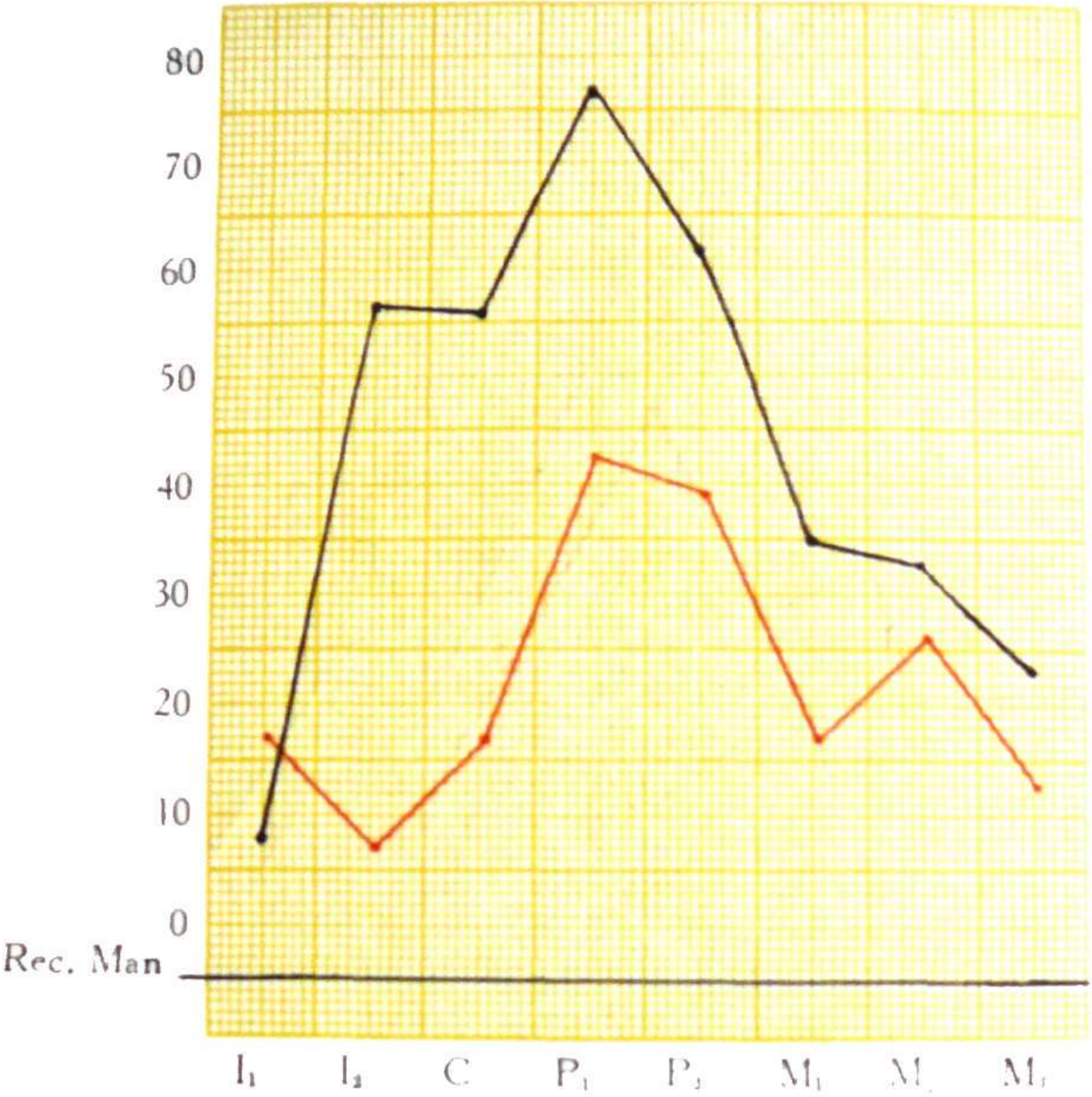

Diagram 24. The same as Diagr. 23 for the lower teeth.

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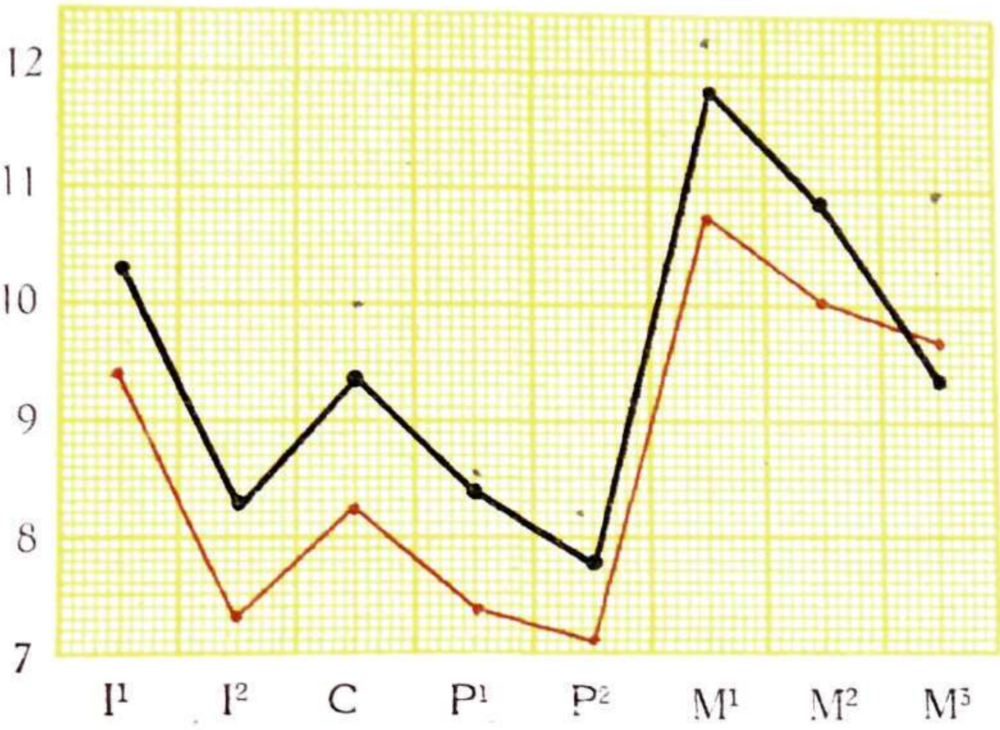

Diagram 25. Length (mesio-distal diameter) of the crowns of the upper teeth of *Sinanthropus* (black) and recent man (red).

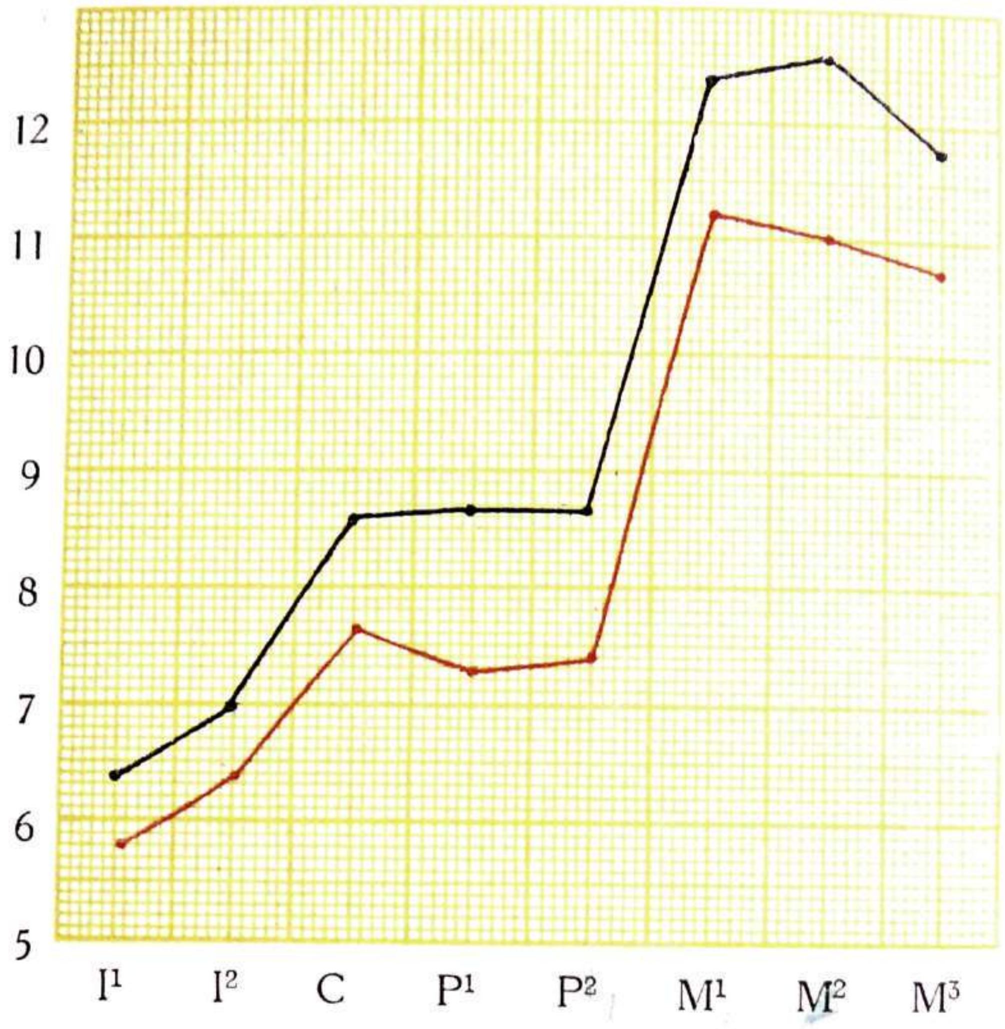

Diagram 26. The same as Diagr. 25 for the lower teeth.

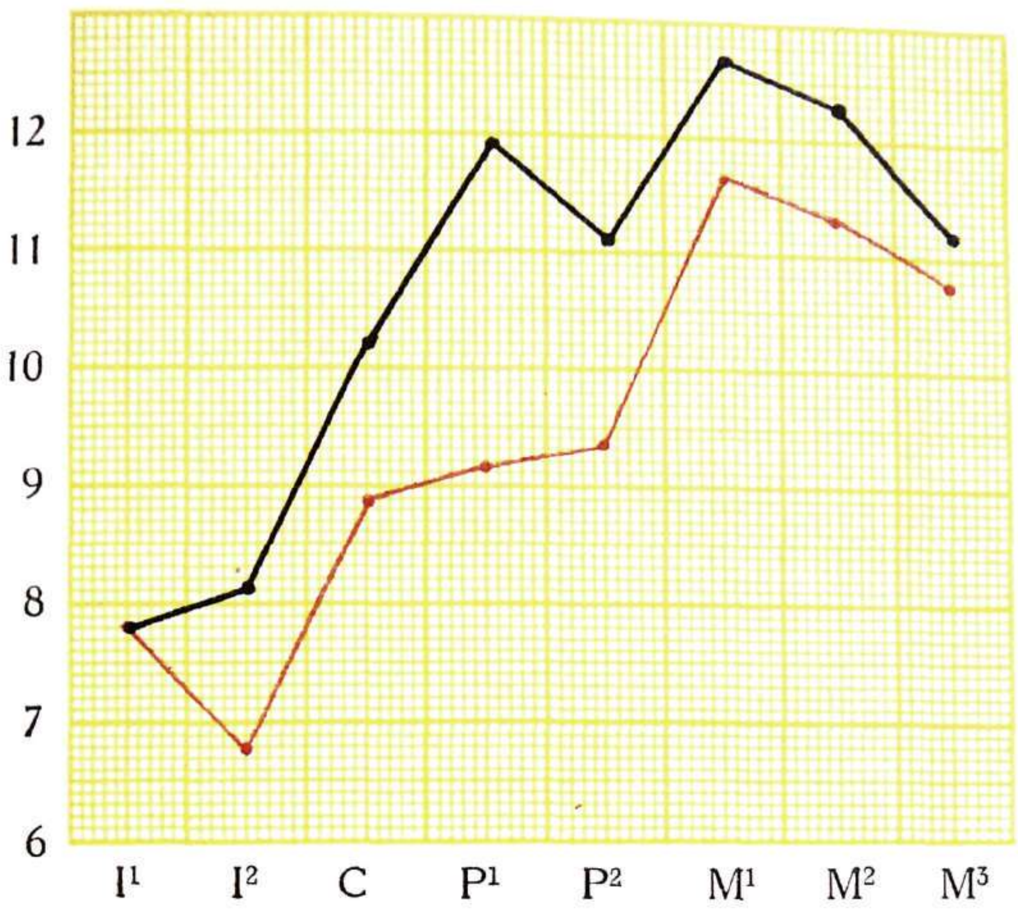

Diagram 27. Breadth (buccal-lingual diameter) of the crowns of the upper teeth of *Sinanthropus* (black) and recent man (red).

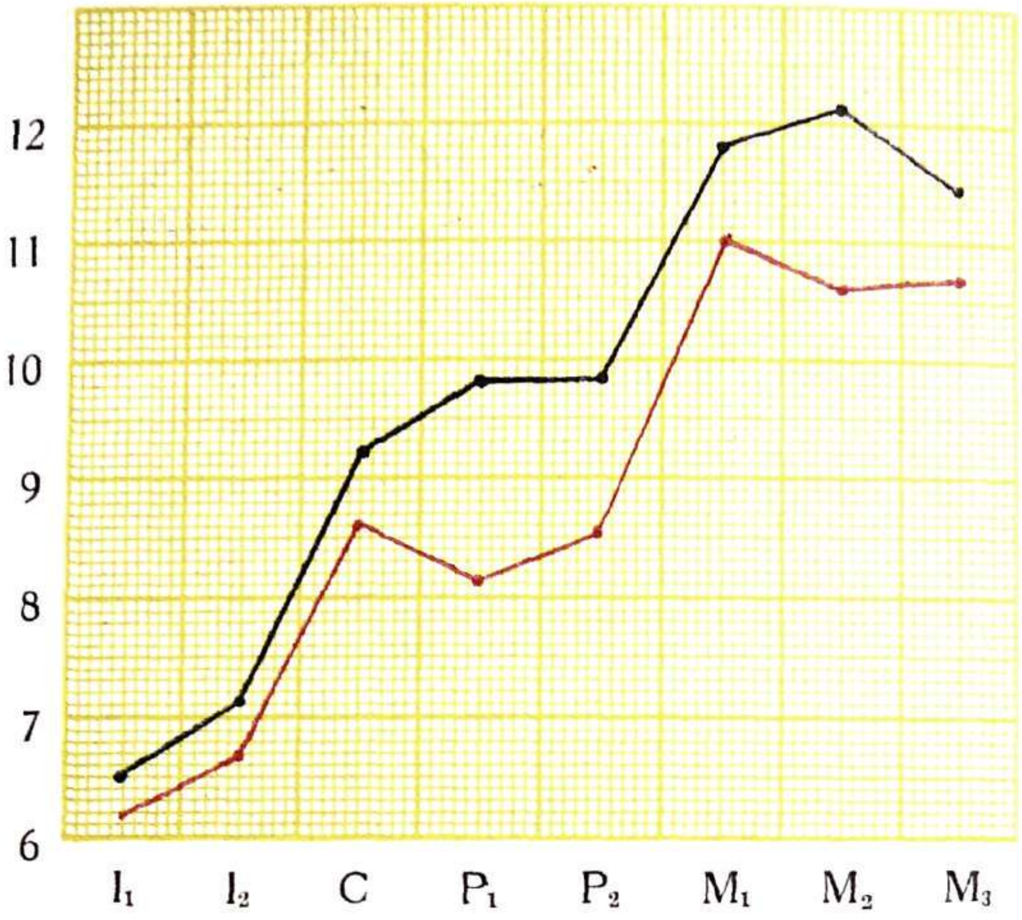

Diagram 28. The same as Diagr. 27 for the lower teeth.

Diagram 29. Length-height index of the crowns of the upper teeth of *Sinanthropus* (black) and recent man (red).

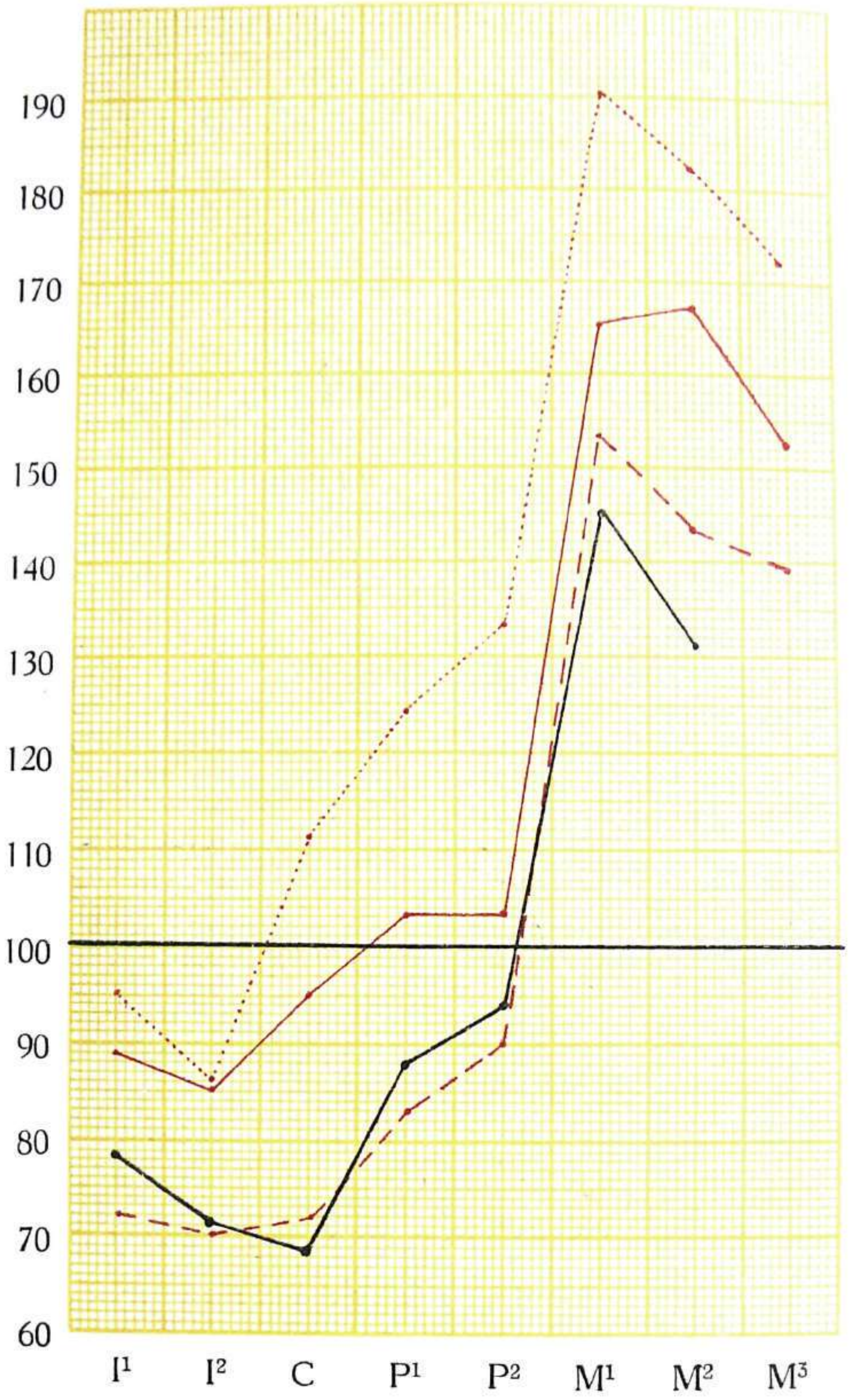

Diagram 30. The same as Diagr. 29 compared with Australian Aboriginal (red dotted line), Japanese (red interrupted line) and Bushman (red full line).

Diagram 31. The same as Diagr. 29 for the lower teeth.

Diagram 32. The same as Diagr. 31 compared with the Australian Aboriginal (red dotted line), Japanese (red interrupted line) and Bushman (red full line).

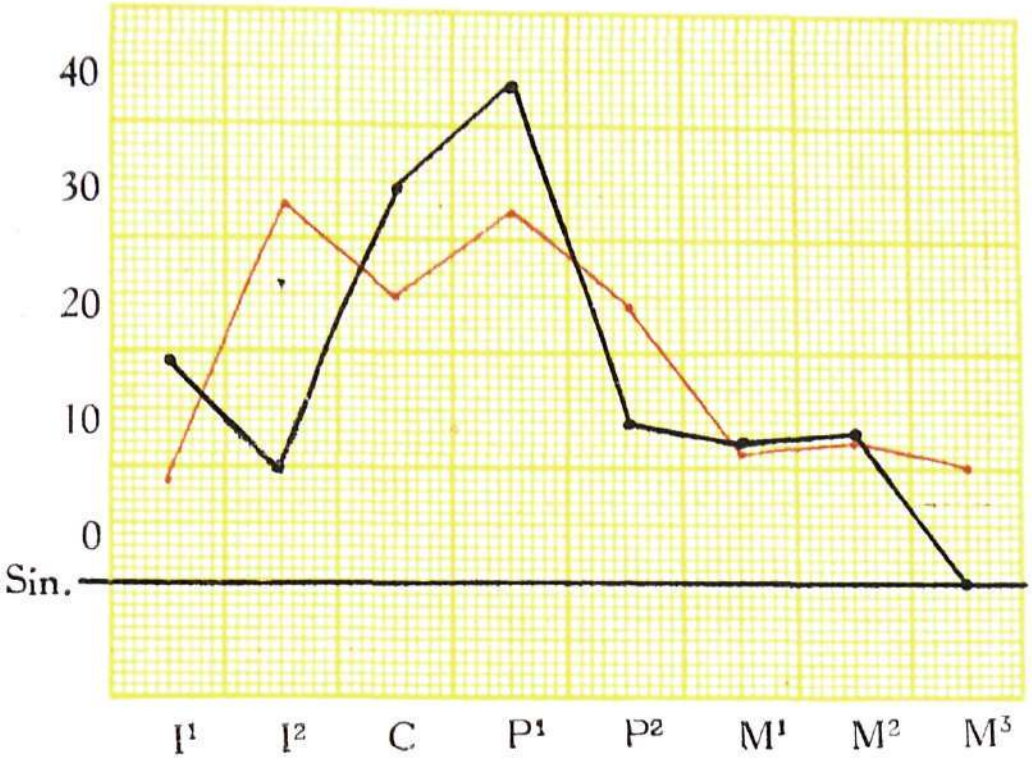

Diagram 33. Decrease of the roots in length (black) and breadth (red) of the upper teeth of recent man expressed in percentage of the respective values for the *Sinanthropus* teeth.

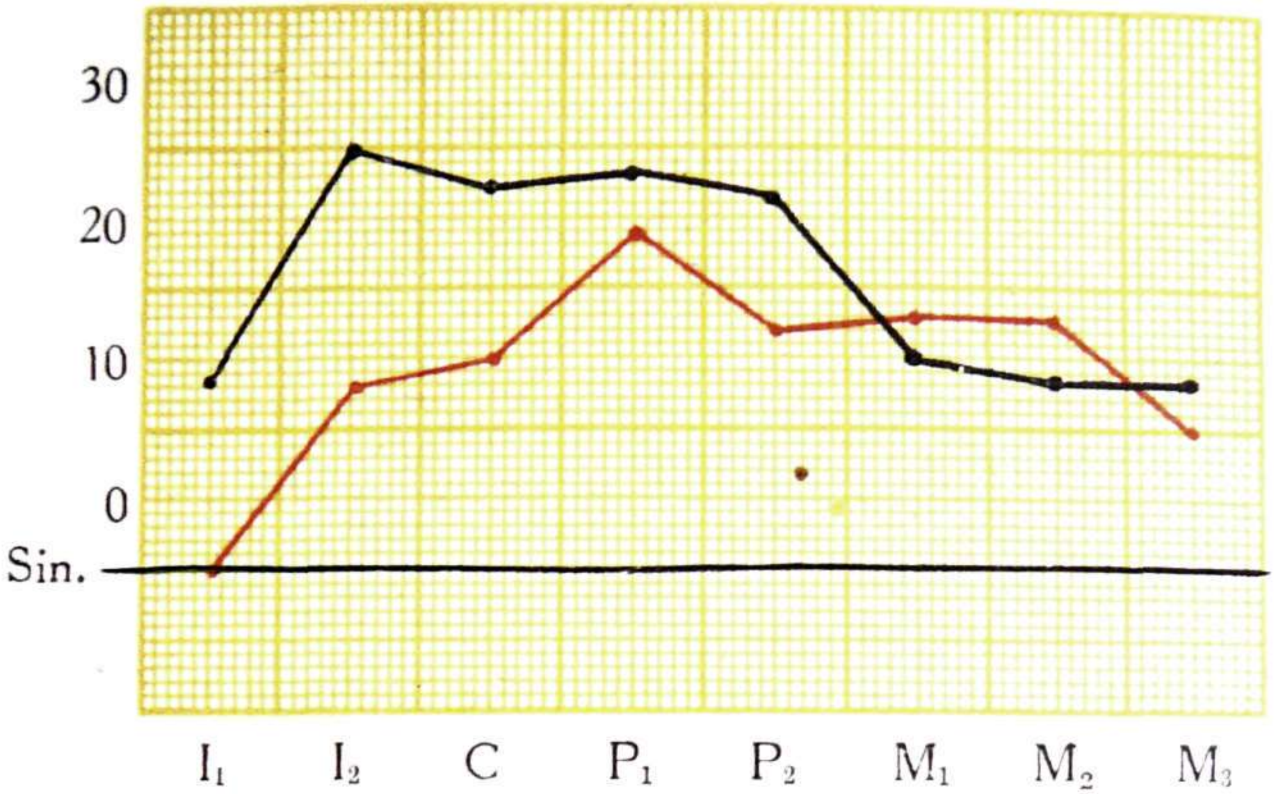

Diagram 34. The same as Diagr. 33 for the lower teeth.

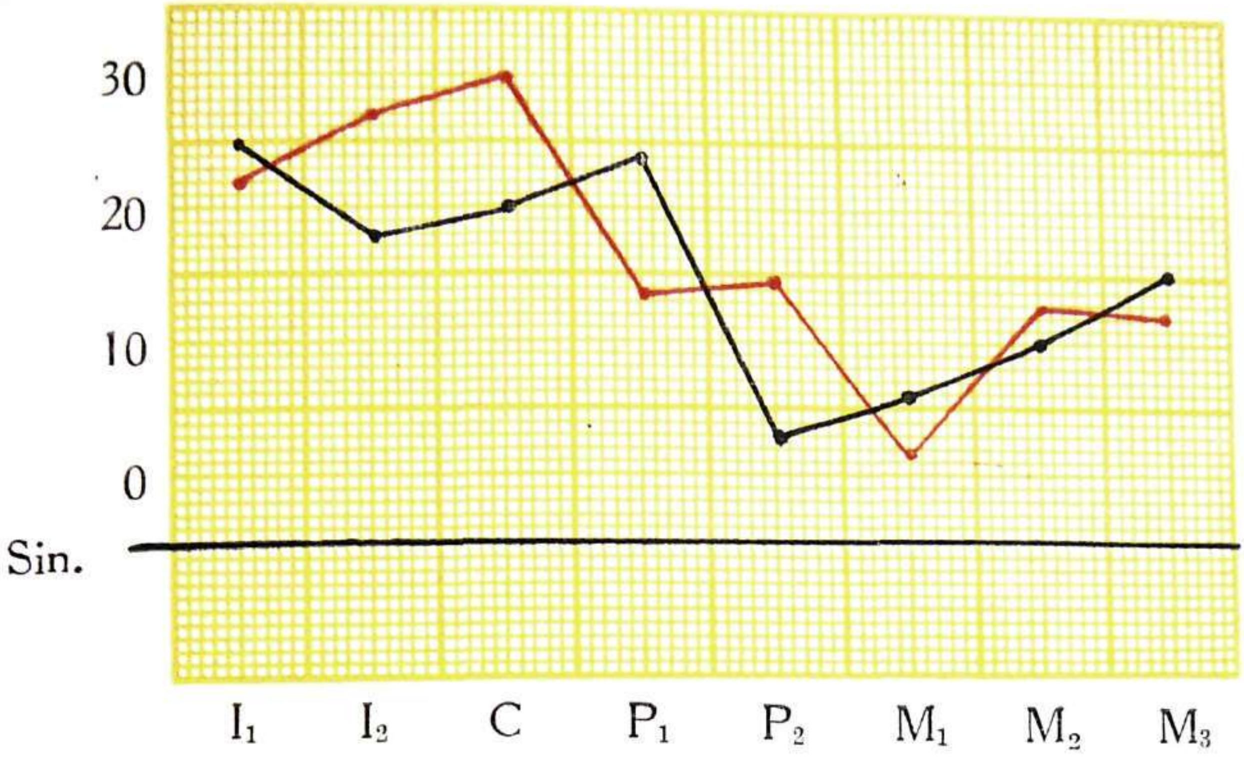

Diagram 35. Decrease of the height of the roots of recent man expressed in percentage of the respective values for *Sinanthropus*. Upper teeth: black; lower teeth: red.

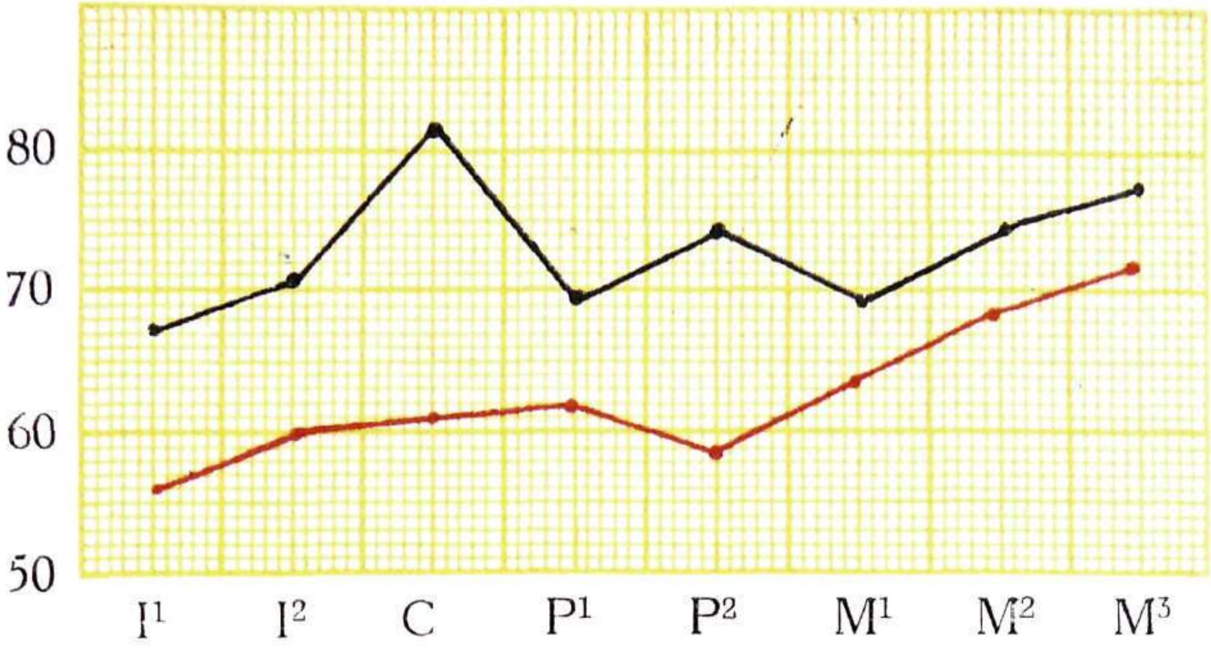

Diagram 36. The ratio of the robustness of the roots of the upper teeth in relation to that of the crowns. *Sinanthropus*: black, recent man: red.

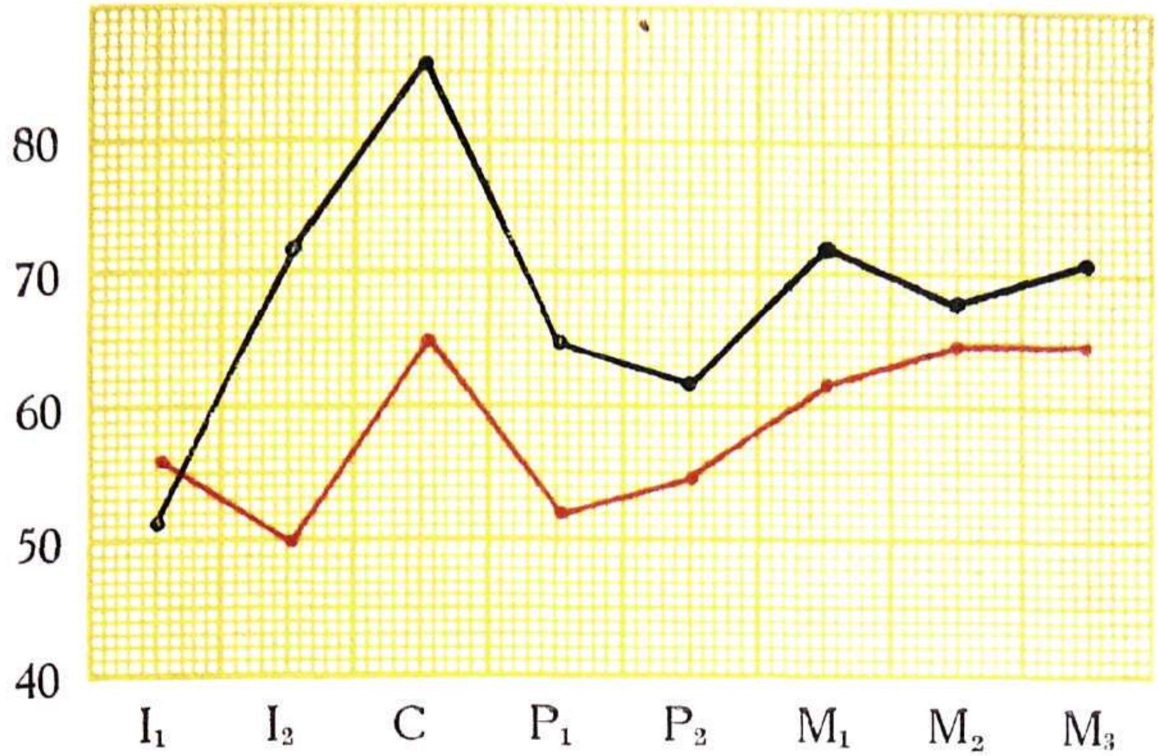

Diagram 37. The same as in Diagr. 36 for the lower teeth.

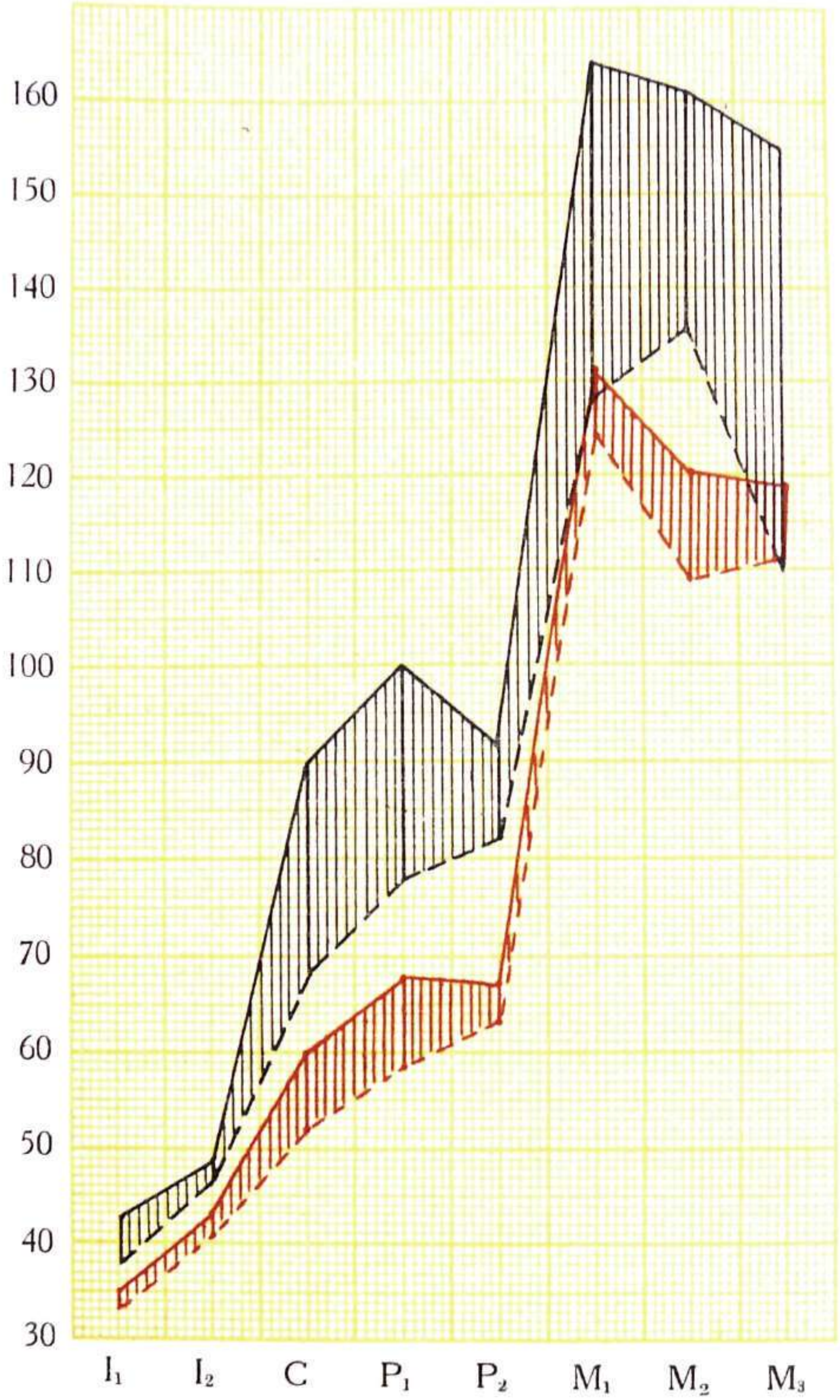

Diagram 38. Robustness of the crowns of *Sinanthropus* lower teeth of male and female individuals (black) compared with recent man—Japanese (red) after Mijsberg (1931). Males full lines, females interrupted lines.

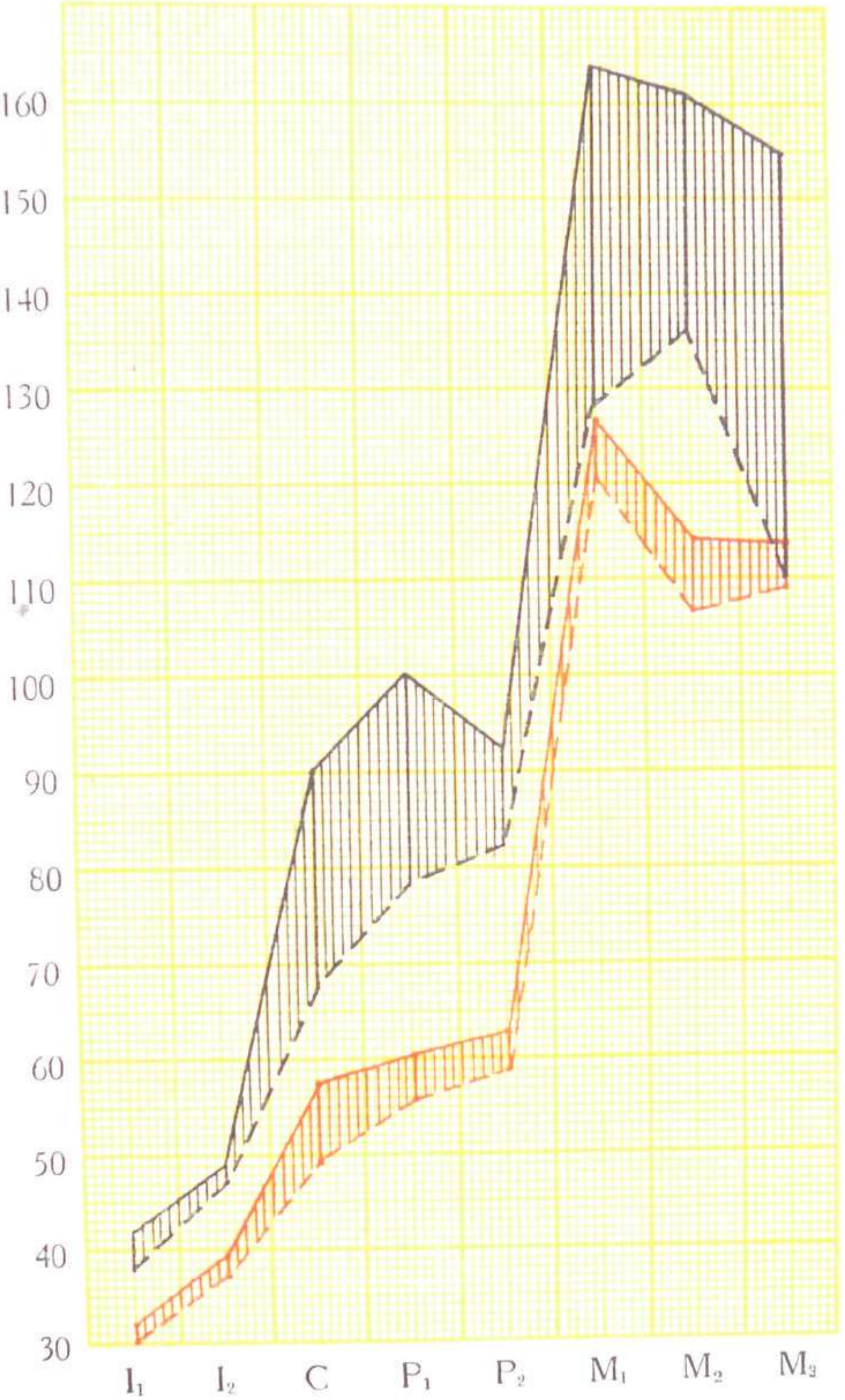

Diagram 39. The same as in Diagr. 38 compared with New-Pommerians of today after Janzer (1927).

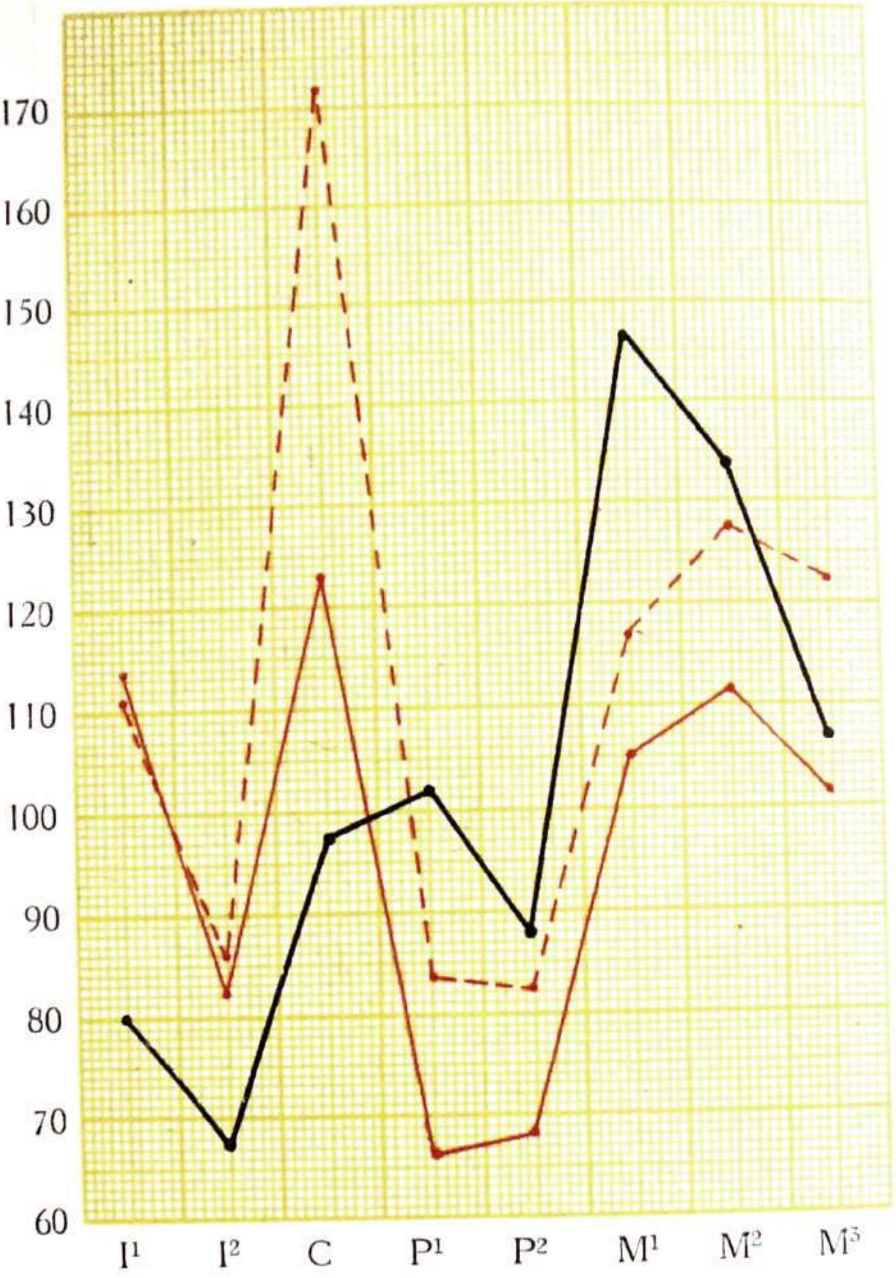

Diagram 40. Robustness of the crowns of the upper teeth of *Sinanthropus* (black) and chimpanzee ♀ (red) and ♂, respectively (red interrupted line).

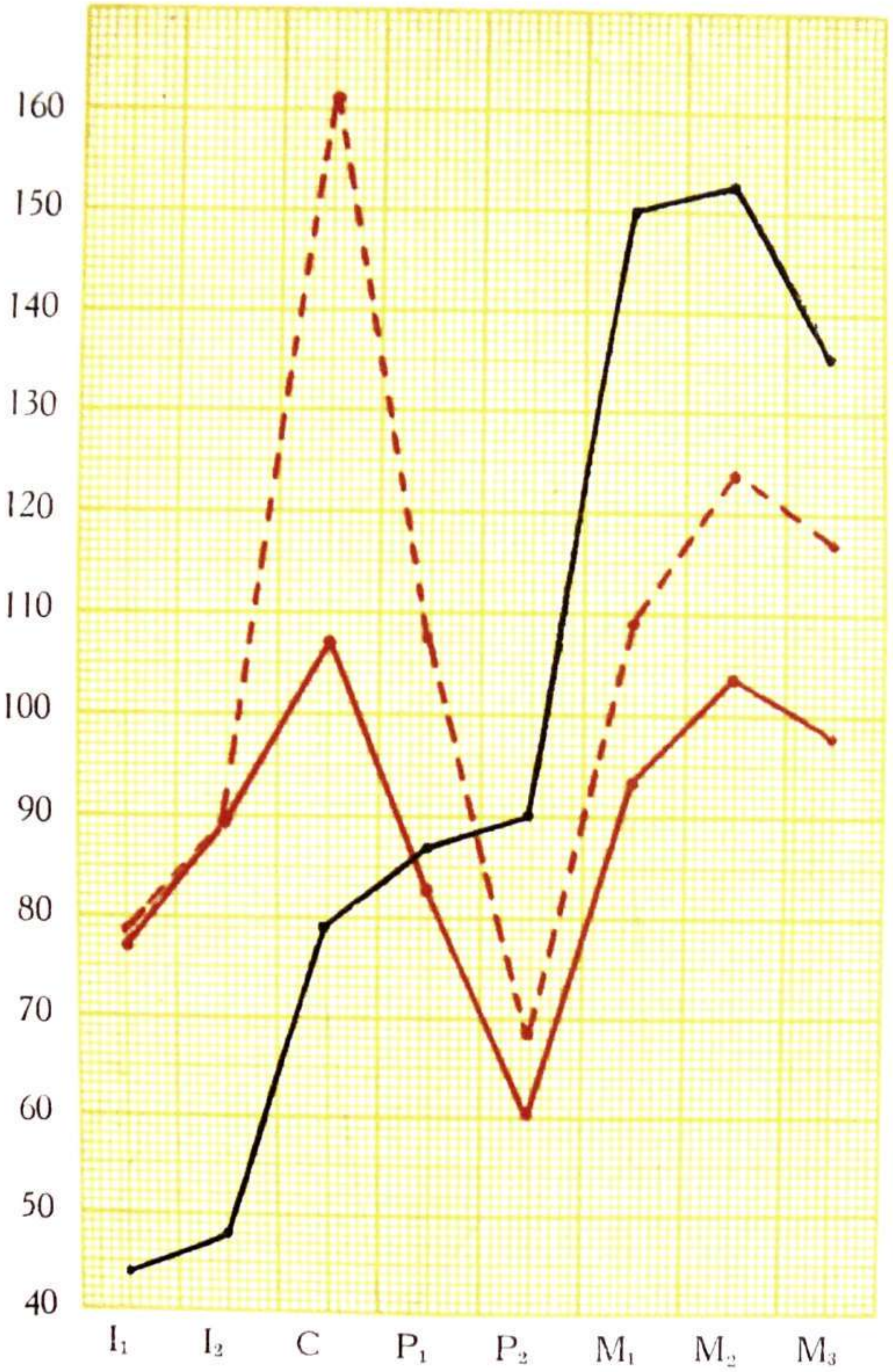

Diagram 41. The same as in Diagr. 40 for the lower teeth.

Diagram 42. Robustness of the crowns of the upper teeth of *Sinanthropus* (black) and gorilla ♀ (red).

Diagram 43. The same as in Diagr. 42 for the lower teeth.

Diagram 44. Robustness of the crowns of the upper teeth of *Sinanthropus* (black) and orang ♀ (red).

Diagram 45. The same as in Diagr. 44 for the lower teeth.

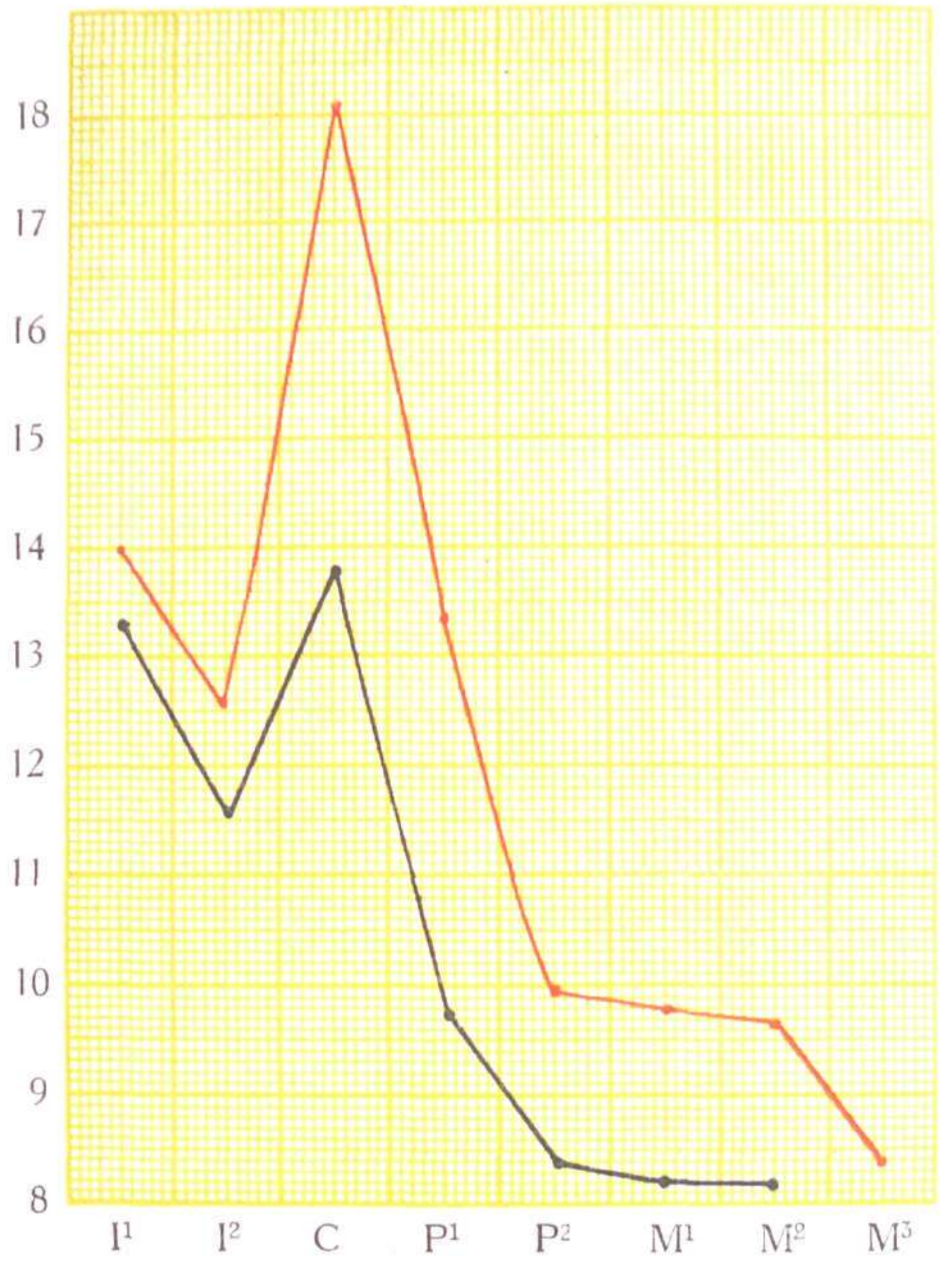

Diagram 46. Height of the crowns of the upper teeth of *Sinanthropus* (black) and female gorilla (red).

Diagram 47. The same as in Diagr. 46 for the lower teeth.

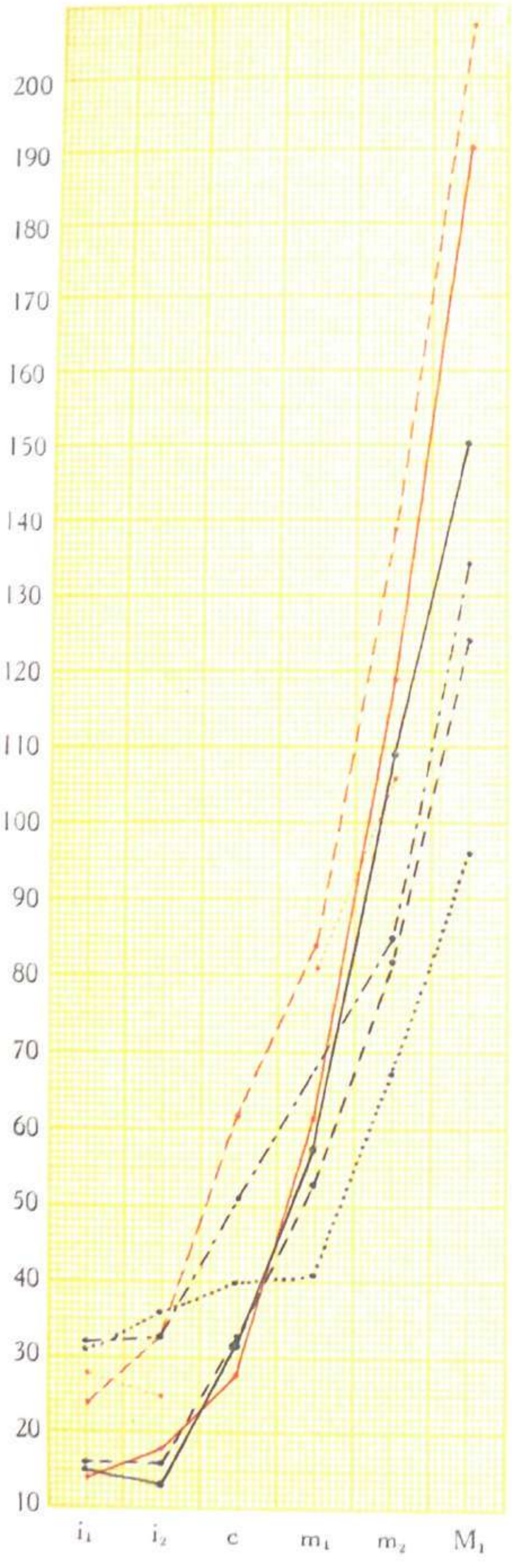

Diagram 48. Robustness of the crowns of the lower deciduous teeth and M_1 of *Sinanthropus* (—), recent man (- -), *Australopithecus* (red straight line). Neanderthaler—Gibraltar child—(red dotted line), gorilla (red interrupted line), orang (·—·), chimpanzee (· · ·).

Diagram 49. Robustness of the crowns of the lower teeth of *Parapithecus* after Schlosser.

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PALÆONTOLOGIA SINICA

THE MANDIBLES OF *SINANTHROPUS PEKINENSIS*: A COMPARATIVE STUDY

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With Text figures 1 to 100, Tables I to XVII and Plates I to XV.

古生物誌

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Peiping 1936

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B. Measurements of the ramus

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INTRODUCTION

Among the remains of fossil man the jaws have at all times occupied a prominent place. I recall the jaw of La Naulette found in 1866 which for a long time was the center of interest and later in 1880 the jaw of Schipka which was not less intensively discussed. Still later, namely in 1907, the jaw of Heidelberg received the widest attention and then in 1914 and 1916 the jaws of Ehringsdorf. Numerous discoveries of jaws were made in connection with skulls and other skeletal remains. Of these the jaws of Spy found in 1886 deserve special mention as well as those ten jaws of Krapina recovered from 1900 to 1905. Considerable attention was also given to the jaw of Piltdown unearthed in 1912, while the jaw fragment of Kedung Brubus recovered by E. Dubois in 1890 and considered by him as being related to *Pithecanthropus* was neglected without any apparent reason.

In Table I a list is given of all the jaws known at present and considered as belonging to fossil hominids, with the exception of those which are necessarily attributed to *Homo sapiens*. The determination of age and sex is made partly according to the respective authors and partly according to Hrdlicka (1930). As to the literature cited this is also taken from Hrdlicka.

All these jaws are related by the fact that they are thick and bulky compared to those of recent man, and that the relief of their surfaces is strongly developed and the chin (mentum osseum) absent. Nevertheless, great differences do exist, namely in size, in the shape of the dental arcade, and in structural details. According to the general opinion they represent a single morphological and palæontological group—except the jaw of Heidelberg and that of Piltdown. The Heidelberg jaw is attributed to the Neanderthal group (*Homo primigenius*). Hitherto, it was always considered a distinct type. The jaw of Piltdown in the pithecoid characters of which all scientists agreed has been combined with the fragments of a brain case found at the same site and together they are considered to belong to a distinct hominid type called *Eoanthropus Dawsoni*. The jaw fragment of Kedung Brubus has as yet not been given any definite recognition.

In comparison with all these jaws the *Sinanthropus* mandible of Choukoutien may claim special interest. According to previous statements chiefly dealing with the skull (Locus E skull) *Sinanthropus* represents a hominid which differs in principle from Neanderthal man by essential characteristics and one which exhibits distinctly more primitive features. The morphological descriptive separation from *Homo primigenius* and the establishment of a new type, namely *Sinanthropus*, therefore appears to be justified. I fully agree with Davidson Black in this regard and have recently (1936) been able to present all the details which prove that *Sinanthropus* is distinctly a type of its own. As I have shown in the same publication, apart from all other details the teeth really constitute the decisive factor for such a classification.

Viewed from this standpoint the question arises as to what extent the jaws also fit into this frame, to what degree the primitiveness of the type is manifest in the jaws and how much they differ from those of the Neanderthal group and that of Heidelberg man. The answer to these questions is facilitated by the fact that the fragments of not less than eleven jaws are at hand of which six are juvenile and five adult of both sexes. All jaws were recovered from Locality I, and, although from various layers, display the same basic features so that they form a uniform group in contrast to other known fossil jaws.

TABLE I

Locality	Year of discovery	First Describer	Age	Supposed Sex
A. *Juvenile mandibles:*				
Schipka	1880	Maska	8-9	?
Krapina A	1900-1905	Gorjanovic-Kramberger	7	?
Krapina B			8	?
Krapina C			13	?
Le Moustier	1908	Klaatsch u. Hauser	16	♂
Ehringsdorf	1916	H. Virchow	10	?
Gibraltar	1926	Miss Garrod	5	♂
B. *Adult mandibles:*				
La Naulette	1866	Dupont		♀
Spy I	1886	Fraipont and Lohest		♀
Spy II	1886			♂
Banolas	1887	Obermaier (1915)		♂
Malarnaud	1889	Fiehol		?
Kedung Brubus	1890	E. Dubois		?
Krapina D	1900-1905	Gorjanovic-Kramberger		♀
Krapina E				♀
Krapina F				♀
Krapina G				♀
Krapina H				♂
Krapina I				♂
Krapina No. 16				♀
Heidelberg	1907	Schoetensack		♂
La Chapelle-aux-Saints	1908	Boule		♂
La Ferrassie	1909			♂
La Quina	1912	H. Martin		?
Piltdown	1912	Dawson & Woodward		?
Ehringsdorf	1916	G. Schwalbe, H. Virchow		♀

In Table II all *Sinanthropus* jaws are listed according to site of recovery, age and sex:

TABLE II

A. Adult *Sinanthropus* jaws of Locality 1 of Choukoutien.

	Locus	No. of the individual*	Sex	Specimen	Previously described	Plate-Figure reference in this publication
1	A	II	♀	Part of the right moiety	Jaw Locus A: Davidson Black, 1929, 1931, 1934.	Pl. I, figs. 1-6; Pl. X, fig. 3.
2	B	II	♂?	Left condyle		
3	G	I	♂	3 pieces of the left and right moieties.	Jaw Loc. G I & II: Davidson Black, 1931, 1933, 1934.	Pl. IV, figs. 1-4; Pl. V, figs. 1-5; Pl. X, fig. 1; Pl. XII, fig. 4.
4	H	I	♀	Frontal part and right moiety	Jaw of the upper travertine: P. Teilhard de Chardin & W. C. Pei (1934).	Pl. VII, figs. 1-5; Pl. VIII, fig. 2; Pl. X, fig. 2.
5	H	IV	♀?	Fragment of the frontal and both adjoining parts	Jaw Locus H IV: Weidenreich, 1935.	Pl. IX, figs. 9-12.

B. Juvenile *Sinanthropus* jaws of Locality 1 of Choukoutien.

	Locus	No. of the individual*	Age	Sex	Specimen	Previously described	Plate-Figure reference in this publication
1	B	I	8-9	♀	Frontal part & right moiety	Jaw Loc. B: Davidson Black, 1929, 1931, 1933, 1934.	Pl. II, figs. 1-7; Pl. VI, figs. 1 & 5; Pl. VIII, fig. 1.
2	B	III	8-9	♂	Fragment of right moiety	F. Weidenreich, 1935	Pl. VIII, figs. 8-13.
3	B	VI	5-6	♀	Fragment of right moiety	F. Weidenreich, 1935	Pl. VIII, figs. 3-7.
4	B	V	11	♂	Frontal part & part of right moiety	F. Weidenreich, 1935	Pl. IX, figs. 1-8.
5	C	I	8-9	♀	Fragment of right ramus	Jaw Loc. C: Davidson Black, 1931, 1933, 1934.	Pl. III, figs. 1-4; Pl. VI, fig. 2
6	F	I	8-9	♂	Fragment of right moiety	Jaw Loc. F: Davidson Black, 1931, 1933, 1934.	Pl. III, figs. 5-8; Pl. VI, fig. 3

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* cf. Table II in my paper entitled "The *Sinanthropus* population. . . .", Bull. Geol. Soc. China, Vol. XIV, No. 4, 1935.

Since the morphological significance of the jaws can only be ascertained by comparing the latter with jaws of fossil and recent man on one hand, and with those of anthropoids on the other, I have laid special stress on such a comparison in this study.

The comparative morphology of hominid jaws constitutes a special problem. Assuming the theory to be correct that recent man developed from a primitive primate corresponding approximately to the general stage of evolution of the anthropoid of today, then it may be expected that the jaws, especially in regard to the degree of prognathism, in the shape of the symphyseal region and in the form of the dental arcade approach this stage more closely the further their type is removed from that of recent man. The same holds good for the teeth. In this respect the discovery of the Heidelberg jaw played an important role. Since, apart from its size and bulkiness the Heidelberg jaw does not differ appreciably from the jaws of the Neanderthal group and since according to the geological conditions the Heidelberg jaw seems much older and more primitive than those of the Neanderthal group, many authors reached the conclusion that such an interpretation was wrong, that is to say, that the hominid jaw even in the early stage of its phylogenetic evolution could not have been too far removed from the type of recent man. The relative smallness of the teeth, especially of the canine of the Heidelberg jaw, somewhat supported such an assumption. It needed only a small step forward to reverse the theory completely and to pretend that the anthropoids of today are the unilaterally specialized descendants of an originally human-like hominid.

In regard to the jaw Bolk (1926) maintained that the first form of hominids and anthropoids had a "mesogeneiotic" jaw from which the human jaw developed in an ortho- and opisthognathous direction, and that of the anthropoids into a prognathous form. Yet I have been able to show (1934) that all comparative facts on hand contradict Bolk's suggestion and that originally the hominid jaw must have been as prognathous as that of the anthropoids. Furthermore, I have proven that, according to the understanding of evolution as advocated particularly by G. Schwalbe (1923), the jaw of recent man resulted from a progressive reduction, especially in the region of the "prelacteal" teeth, manifesting itself primarily in a retraction of the front teeth and as a consequence thereof in a projection of the chin (mentum osseum). Finally, I was able to demonstrate that this reduction and change is only part of the general transformation of the whole skull. The original relation of small brain-case and a large masticatory apparatus has been reversed during phylogenetic evolution.

Beyond doubt *Sinanthropus pekinensis* represents the most primitive and geologically speaking the most ancient hominid known hitherto. With sufficient material of brain cases, jaws and teeth preserved, its completeness has enabled us to form a better judgement of the questions raised above. Although in this publication I refer to the jaws only, the statements in regard to the problem as a whole also have to be included.

I. DESCRIPTION OF THE INDIVIDUAL FRAGMENTS

In the description of the specimens I shall follow the order adopted in Table II of my previous publication (1935), first describing the adult and then the juvenile jaws.

A. ADULT JAWS:

1. Jaw A II (Jaw Locus A), Plate I, figs. 1-6; Plate X, fig. 8. This fragment was recovered from Locality 1 towards the close of the 1928 excavations. It is highly mineralized and deeply pigmented (Davidson Black, 1933). The specimen comprises the greater part of the right body of the lower jaw, its posterior part

beginning at about 10 mm. behind M_3, just at the site of attachment to the ramus which is missing entirely, and in front it ends at about the middle of the alveolus of I_2. The three molars are *in situ*: the first one is slightly damaged on the lingual side, the third one is evidently smaller in length and breadth than the other two molars. All three teeth are rather strongly worn. The alveoli of both premolars, the canine and the distal half of that of the lateral incisor are preserved. The lower margin of the body is intact only in the region below the second premolar. Behind this region it is broken off.

The height of the preserved part just at the frontal margin of the foramen mentale between P_1 and P_2 is 25.5 mm. The thickness in the region of the second molar is 15.7 mm.

2. Jaw B II. This fragment was found in 1935 during the preparation in the laboratory of material from sub-locality B excavated in 1928 by Birger Bohlin. Like all the other findings of this sub-locality the specimen is highly mineralized.

The specimen consists of a left condyle and neck. It is compressed in an anterior-posterior direction and both the lateral and medial parts are broken off.

On account of the fragmentary condition of Jaw B II no illustrations are given.

3. Jaw G I (Jaw Locus G I and G II), Plate IV, figs. 1-4; Plate V, figs. 1-5; Plate X, fig. 1; Plate XII, fig. 4. This jaw is composed of three fragments two of which have already been described by Davidson Black (1931, 1933). Black designated one as Locus G I and the other as Locus G II because he believed them to belong to two different individuals, though he also conceded the possibility that they might represent parts of a single jaw specimen (1933). Both fragments were recovered by W. C. Pei during the summer 1931 within the so-called Quartz Horizon 2 of the Kotzetang Cave of Locality 1 and were found on the same level at a distance of about 80 cms. from each other (compare W. C. Pei, 1931). The third piece was collected later from material derived from the same place.

All three specimens are lightly mineralized, the first and second being dark-brown in colour, and the third one considerably lighter. The first fragment (Black's jaw G I) comprises the whole left side of the body including the anterior part of the whole ramus with the coronoid portion—with only the top of the latter missing—and the complete set of teeth from the last molar to the medial incisor. The front end is broken off in an oblique line running from the alveolar border in the region of I_1 to the lower margin of the jaw body which it reaches in the level of the first premolar.

The second fragment (Black's jaw G II) is of the right side and comprises the complete ramus with both condylar and coronoid portions together with the alveolar part of the second and third molar. The line of the broken surface runs obliquely from a point in front of the second molar to the jaw angle. Both molars are preserved but rather worn and the crown and neck of M_2 are damaged. The defects of the latter were filled with celerit by Davidson Black. A small part of the margin of the mandibular notch is missing.

The third fragment is a very small piece and comprises the left first premolar with the adjoining part of the lingual surface of the lower jaw. The whole labial part is broken off so that only the lingual walls of the alveoli of the canine and those of both premolars are partly preserved. The tooth is worn.

All three fragments are very robust and thick, the larger ones being very high. The height of the first fragment measured in the same region as in the case of jaw A II (see above) is 34.4 compared to 25.5 mm in the latter. The greatest thickness in the area of the second molar is 18.0 mm in the fragment of the left side while in that of the right side it is 18.3. The thickness of the bone in the middle of P_1 is 16.3 in the fragment of the left side of the jaw and the same in the third fragment. In both specimens the labial wall of the alveolus is missing.

Notwithstanding the opinion expressed by Davidson Black, I believe (1935), that the fragments of the two different sides of the jaw (G I and II) as well as that found later belong to one and the same individual. The reader is referred to the explanations given below in support of such an assumption (p. 18).

4. Jaw H I, Plate VII, figs. 1-5, Plate VIII, fig. 2, Plate X, fig. 2. This lower jaw was recovered during the 1934 spring excavations of the "Upper travertine" layer of Locality I by Mr. W. C. Pei (Teilhard de Chardin and Pei, 1934). This layer proved to be very rich in carefully worked implements and was later designated as Locus H. The fragment in question represents the complete right half of a jaw with body and ramus. Only the margin of the mandibular notch is missisg. The condyle is damaged: the inner part is cracked, the outer part is partly broken off. The symphyseal part of the jaw is preserved and intact. The line of the broken surface runs from the middle of the alveolus of the lateral incisor in oblique direction to the lower margin in the region of the first premolar.

The third molar is preserved and very strongly worn. All other teeth are missing but the alveoli are well preserved, with the exception of the outer border of the alveoli of the first and second molars and both medial incisors which are broken off.

This jaw resembles quite closely that listed as A II, not only in size, but also in height and thickness. The height in the region between P_1 and P_2 is 27.5 mm, the thickness in the region of M_3 15.4 mm.

5. Jaw H IV, Plate IX, figs. 9-12. This fragment was found in the laboratory in 1935 while preparing the material derived from sub-locality H which was excavated by Mr. Pei in 1934.

The fragment comprises the frontal part of the lower jaw and the upper part of the right side including the first molar. The left side is badly damaged. The whole exterior wall is broken off beginning with the lateral incisor to about the region of the mandibular foramen. Nothing else is preserved but the inner surface with a height of approximately 1.5 cm and a thickness of about 0.3 cm. The front part of the lower border is also broken off quite extensively. As to teeth, those of the right side from the lateral incisor to the first molar are preserved. The teeth are very strongly worn and the entire chewing surface consists of secondary dentine. The exterior parts of both premolars are broken. The alveoli from the right medial incisor to the left second premolar are recognizable by their interior wall which are partly preserved.

This fragment resembles both in the height of its frontal part and its thickness the jaw specimens designated as H I and A II. It is very highly mineralized.

B. JUVENILE JAWS:

1. Jaw B I (Jaw Locus B), Plate II, figs. 1-7; Plate VI, figs. 1 & 5, Plate VIII, fig. 1. In 1929 and 1933 Davidson Black gave a detailed description of the finding and preparation of this lower jaw discovered during the summer excavation of 1928. Originally the jaw fragment consisted of two parts, namely an anterior part comprising the rather well preserved and complete symphysis region and a posterior part embracing the right adjoining body together with the ramus. Although this latter part was broken into several pieces a complete

reconstruction of it was possible. In figs. 1 and 2 (Plate II) the fractures can be seen. In regard to teeth, the permanent incisors were found fixed in the symphyseal part, but the deciduous teeth and the germs of both permanent premolars of the right side were mixed with other bone fragments. The crown of the first permanent molar was broken off but its root was preserved within the original piece of bone. Davidson Black gave an illustration of the partly restored jaw without these milk molars and the crown of M_1 so that the unerupted permanent premolars can be seen (fig. 5, Plate II). In the completely restored jaw the canine, milk molars and the first permanent molar have been fixed with wax in their original positions.

The restored jaw therefore comprises the symphysis region beginning with the left canine, the whole body and the greatest part of the ramus of the right side. Only the coronoid process and the pertaining part of the ramus are broken off. Also the main part of the condyle itself is missing.

The milk teeth are rather worn, but the first permanent molar and the incisors only show a slight wear. I removed again a part of the restored piece and extracted both premolars so as to be able to study them carefully.

2. Jaw B III - Plate VIII, figs. 8-13. This fragment was discovered in a travertine block of Locus B excavated by Mr. Pei in 1932. It was partly prepared in April 1935 and consisted of two pieces which I fitted together. The restored fragment represents a part of the right side of the body beginning just in the middle line and ending behind the first permanent molar. Both ends are damaged, especially the posterior end.

All teeth are preserved, at least by their roots. The crowns of both incisors are broken off, these being the permanent ones. The crown of the canine (milk canine) is likewise completely missing. The second milk molar is totally preserved, but rather worn. Of the first milk molar the greatest part of the crown is broken off. Very well preserved and not worn is the first permanent molar which had just erupted.

3. Jaw B IV, Plate VIII, figs. 3-7. This fragment was recovered in the laboratory in 1935 during the preparation of material from Locus B excavated by Birger Bohlin in 1928. It comprises the right side of the body beginning with the middle line and ending behind the first permanent molar. All teeth, with the exception of the latter, are preserved, representing together the entire set of the deciduous teeth of this side. The first permanent molar was just in the stage of erupting but is completely broken off; a few splinters can be observed to adhere to the upper surface.

The symphysis region is damaged on the inner side. The lower margin only is preserved in the level of the canine. Behind this it is broken off.

4. Jaw B V, Plate IX, figs. 1-8. Like jaw B IV this fragment of the lower jaw was also discovered in the laboratory in 1935 during the preparation of material from Locus B collected by Birger Bohlin in 1928.

The fragment comprises the symphysis region and the adjoining part of the right side of the body up to the distal point of the second premolar. On the left side only the inner wall of the body is preserved up to approximately the second premolar. The exterior wall of this part is broken off. The lower margin is only preserved on the left side from the middle line up to the level of the first premolar. Both the exterior and the interior surfaces of the symphyseal part are slightly damaged. In regard to the teeth, the four permanent incisors are preserved but slightly worn. One half of the right canine is erupted while the left one is cutting the gum. Since the outer wall is broken off in this specimen, the tooth may be seen in its natural position in the bone. The right first premolar has just erupted. In place of the second premolar there is the second milk molar which is rather strongly worn; below this the second permanent premolar was exposed. I removed it for the purpose of making a better study.

5. Jaw C I (jaw Locus C), Plate III, figs. 5-8; Plate II, fig. 3. This fragment was found among the fossiliferous material excavated in 1929 from Locus C of the north "Lower fissure."

It is a very small piece and comprises only the region of the angle of the right side from the interior-posterior margin until the alveolar surface. On the latter there is visible one unerupted molar.

Davidson Black believed this tooth to be a third molar while I consider it to represent a second molar (Weidenreich, 1935). Further reference will be given in the following pages.

6. Jaw F I (jaw Locus F), Plate III, figs. 5-8; Plate VI, fig. 3. In 1930 Mr. Pei discovered this specimen *in situ* in the "Lower Cave."

It comprises the posterior part of the right side of a lower jaw beginning immediately in front of the first molar and embracing the whole ramus. The top of the coronoid process and a small piece of the angle are broken off as is also the posterior wall of the condyle.

As to the teeth preserved, the first permanent molar is *in situ* and only slightly worn. Behind this the mastication surface of the second permanent molar is to be seen but the tooth still is completely embedded in the bone.

II. GENERAL APPEARANCE AND AGE OF THE JAW SPECIMENS

The four adult jaws — the specimen listed as B II being excluded on account of its small size — reveal very clearly different types, namely a small one and a large one. The latter is represented by jaw G I, the former by jaws A II, H I and H IV.

These differences can be seen quite clearly by comparing the height of the body of the two respective types. As stated above, G I has a height of 34.4 mm just in front of the mental foramen while A II only has a height of 25.5 mm and H I one of 27.5 mm. In H IV the lower margin of this point is broken off so that the height cannot be determined at this particular point, but instead that of the symphyseal region is taken which reads 30.9 mm. H I is slightly higher (32.3 mm) in this region, while in G I this height is approximately 40 mm.

It is important to note that the differences in thickness are not so great but nevertheless evident. The greatest thickness in the region of M_1 in G I is 17.3 mm, in A II 15.4 mm, in H I 14.9 mm and in H IV 15.7 mm.

The size of the teeth corresponds very distinctly to the degree of robustness of the jaws. Because in the case of H I M_1 is missing, I made use of the length and breadth measurements of the relevant alveolus.

TABLE III

a. Size of the alveolus of M_1

	Length	Breadth	Length × breadth
G I	11.4	11.6	132
A II	10.0	10.1	101
H I	10.9	8.7	95
H IV	10.9?	10.7	117

b. Size of M_1

	Length	Breadth	Length × breadth
G I	12.2	12.7	155
A II	11.2	11.2	125
H IV	10.9	11.0	120

In my paper on the *Sinanthropus* population (1935) I already called attention to the fact that extraordinary differences in size of teeth existed in *Sinanthropus* and that such was true for all kinds of teeth. I considered these differences as dependent upon sex and therefore attributed the large teeth to the male and the small ones to the female sex.

Since these differences in the size of the teeth completely conform to those observed in the size and robustness of the jaws, there can be no doubt that my assumption is correct. Therefore jaw G I must belong to a male individual and the jaws A II, H I and H IV to females.

As to the age, all that can be stated is that all four jaws belong to adult individuals. If the degree of attrition is a reliable means of determining the age, then the individuals of H I and H IV were very old and in any case older than those of jaws A II and G I, both of which may have been of approximately the same age.

For the determination of the exact age of the six juvenile *Sinanthropus* mandibles the dentition serves as the best basis. However, it should be remembered that the ages of the individuals concerned which are found by comparison with corresponding specimens of recent man may not indicate their actual ages, for the possibility cannot be excluded that in *Sinanthropus* as well as in anthropoids of today the process of the entire dentition requires a much shorter time than in recent man. Hence the ages indicated herein present nothing else but a scale for the relative differences in age when comparing the juvenile mandibles with each other or with the adult individuals of the same hominid type.

The age of the individual *Sinanthropus* B I is estimated to be 8-9 years, since the first permanent molar and the permanent incisors on the one hand and the milk canine and the two milk molars on the other compose the set of teeth (Plate II, fig. 1, 2, 3, 5-7). The skiagram (Plate VI, figs. 1, 5) reveals that the germs of the permanent canines, the two premolars and the second permanent molar are present within the jaw in their corresponding sites of lodgement, both premolars having been subsequently replaced by Davidson Black (see above).

The age of the individual B III is about the same as that of B I. The crowns of the permanent incisors are broken off (Plate VIII, figs. 8-10) so that it is difficult to recognize their character by superficial examination. However, the fact that we are dealing with the permanent teeth is proven by the thickness of the preserved tooth necks and by the skiagram (fig. 10) not showing the presence of germs in the respective sites. This skiagram reveals the same conditions for the germs of the permanent canine and for the two premolars. The first molar is erupted and very slightly worn, although it has not yet completely reached the level of the masticatory surface.

Sinanthropus jaw B IV represents a much younger individual. It has all the milk teeth (Plate VIII, figs. 3-7) which are slightly worn. The first permanent molar must have been in the stage of eruption since the empty cavity in which it was embedded is still exposed (fig. 7), and several splinters can be seen to adhere to the surface. The skiagram (fig. 5) exhibits all the germs of the permanent teeth from I_1 up to P_2. Hence the child B IV must have been approximately 5-6 years old.

Sinanthropus jaw B V presents a more advanced stage of dentition (Plate IX, figs. 1-8). Not only the permanent incisors but also the first premolar are in their definite sites. Both canines are just erupting. Only the second milk molar is still present, the second premolar being exposed below the former. The skiagrams (figs. 3 and 8) demonstrate those teeth which have partly erupted or not yet erupted. The age of this child is therefore about 11 years.

Sinanthropus jaw C I only represented by the region of the angle of the ramus and the germ of a molar exposed with its masticatory surface (Plate III, figs. 1-4) was considered by Davidson Black as that of an adult individual because he took the molar in question for M_3. However, the size of the whole fragment C I corresponds almost exactly to the respective region of the child jaw F I and differs considerably from those of the two adult jaws H I and G I, and it should be noted in this connection that the ramus of H I is smaller than that of the jaw G I. Jaw C I therefore cannot belong to an adult individual. Hence the germ of the molar is that of M_2 and since M_3 does not appear on the skiagram (Plate VI, fig. 2) the individual in question cannot be older than 8 or 9 years which again agrees fully with the size of the fragment.

The age of the *Sinanthropus* individual F I is almost the same as that of the individual C I. The first permanent molar is in its definite position and already worn. The second permanent molar seems to be just erupting (Plate III, figs. 5-7). The skiagram (Plate VI, fig. 3) shows the latter tooth more in detail. The germ of the third molar is not yet recognizable. The skiagram of a modern North Chinese child (Plate VI, fig. 4) reveals the same feature, and in this case also the germ of the third molar is not yet developed. Jaw F I must therefore belong to a child of about 8-9 years.

As to the sex of the juvenile *Sinanthropus* mandibles there is no other reliable criterion for the determination available but the size of the permanent teeth. The robustness of the jaws themselves is also an uncertain factor because of lack of sufficient preserved material of different corresponding ages. As listed in Table II (p. 9) I believe the mandibles B I, B IV and C I to be those of female and the mandibles B II, B V and F I those of male individuals.

III. RECONSTRUCTIONS

In order to understand better the characteristic appearance of the jaws and also to demonstrate clearer the differences of size and sex, I have made a reconstruction of the three best preserved jaws, namely that of jaw G I as representative of the *Sinanthropus* male, that of jaw H I as representative of the *Sinanthropus* female and that of jaw B I as representative of the *Sinanthropus* child of about 8-9 years.

a. Jaw G I (Plates XI-XV, fig. 1 and Plate X, figs. 7 and 8). As mentioned in the description of this jaw given above, Davidson Black at first (1931) did not believe that the fragment of the left side (G I) and that of the right (G II) belonged to the same jaw and individual. He believed the degree of attrition to be different in M_2 and M_3. Yet in a later publication (1933) he admitted the possibility that the two specimens nevertheless might be parts of the same jaw.

I regard this latter opinion as the more probable one. Firstly, as stated above, on account of the finding conditions described in detail by W. C. Pei (1931) and illustrated in his figures A and B, p. 118. Both fragments were namely lying on the same level within a distance of only 80 cm. Furthermore, both fragments exhibit the same degree of roubstness and their rami — as far as they are preserved — are of the same height. The only difference is that the right coronoid process and the anterior border of the ramus is slightly thicker and broader than the left one. In conformity with this appearance the lingual alveolar border in the region of M_3 and M_2 is slightly more protruding on the right side than on the left one. Yet these differences in no way exceed the degree of asymmetry very frequently found in recent man, the right side exceeding the left one. As to the size of the molars (M_2 and M_3) of both sides, the difference is insignificant: the right M_2 is 0.3 mm and M_3 0.5 mm longer than the left molars, the breadth being the same in both (Plate IV, fig. 3 and Plate V, fig. 5). It is difficult to judge the right M_2 with regard to attrition as the greatest part of the chewing surface is broken off and replaced by an artificial filling material during the course of preparation. Only a narrow brim slightly broader on the labial side is preserved. In these preserved regions no difference is recognizable either in the degree or in the kind of attrition.

However in regard to M_3 there really is a difference. It is true that the general degree of attrition is the same in both teeth but the right one is slightly less worn in the region of the anterior lingual cusp than the left. This condition is the only difference to be observed. Incidentally, the third molars of a mandible of our prehistoric Kansu series (No. 400/1) exhibit almost exactly the very same differences. The same is furthermore also true in the case of a female gorilla in our collection (No. 328).

I therefore *do not* believe that the slight deviation in kind of attrition justifies the attribution of the two fragments to different mandibles and individuals.

Still another fact is to be added. Several months after the recovery of the two fragments mentioned above a right lower premolar and a small piece of a mandible (textfig. 39) was found in the loose material from the same site which was brought to the laboratory for preparation. The bone fragment turned out to be a part of the lingual side of the lower jaw with parts of the walls of the alveoli of C, P_1 and P_2. The isolated P_1 fitted perfectly. Both tooth and bone fragment agree completely in size and robustness with the corresponding parts of the well preserved left moiety (G I). The small fragment in particular shows the characteristic exostesis — torus mandibularis — in the region of the interior alveolar border (cf. p. 52 & ff). The size of the right P_1 and the kind and degree of attrition are precisely the same as in the case of P_1 and the left side which was embedded in the jaw. Therefore, there can remain no doubt that this specimen belongs to the same mandible as the fragment of the left side (G I). This bone fragment and the relevant P_1 were not mentioned in Davidson Black's publications.

Although Davidson Black was not positive that G I and G II belonged together, he nevertheless attempted to make a reconstruction of the jaw in the form of a drawing (1933, figs. 42 and 43; 1934, fig. 14). As the symphysis was missing and therefore the exact form of the dental arcade in the frontal part uncertain, Davidson Black used the preserved symphyseal part of the juvenile mandible of Locus B (B I) as a standard and modelled the adult jaw after the juvenile one.

Since we now have that small piece with a part of the alveoli of C, P_1 and P_2, the reconstruction of the symphyseal part has been simplified, for this fragment reveals not only a part of the right interior surface of the jaw but also the degree of its curvature as far as the distal margin of I_1. To the fragment of the left side there still is adherent a very small piece of the right side just immediately behind the right I_1 so that in reality not more than about 2 mm in length of bony substance is missing in the gap between the left fragment (G I) and the third alveolar fragment.

Furthermore, it is important that the entire dental arcade of the left side from M_3 to I_1 is preserved. This arcade takes a remarkably flat course in its anterior segment and differs very considerably by this fact from the jaw of Heidelberg, and those of the Neanderthal group. These latter are appreciably bent mesially from P_1 in a frontal direction (textfig. 77). The frontal part of the arcade must therefore have been very narrowly curved. The almost completely preserved interior rounding of the alveolar part points to the same supposition. As the body of the jaw is relatively long the more or less wide frontal part of the dental arcade must induce a correspondingly wider width between the condyles. But this distance cannot exceed a certain degree, for it depends on the breadth of the brain case or its base, respectively.

The orientation of the left side (G I) with regard to the longitudinal axis follows directly from the position of the front teeth. It is to be placed in such a plane as to bring the longitudinal axis of the teeth in vertical position. Should the frontal part of the dental arcade of the reconstruction have been widened too much and the distance of the condyles kept within reasonable limits, then the roots of the incisors would tend to deviate from the vertical direction to a laterally declined one and the line of the mastication surface of the frontal teeth would slope to the median plane. The possibilities for reconstruction therefore are very limited. That the reconstruction I made does not differ significantly from the true form is indicated by the degree of curvature of the dental arcade which conforms completely to that of the jaw H I in which the symphyseal part is preserved and in which therefore the curvature is fixed beyond doubt (see below). In addition, jaws H IV and B V provide good criteria for the form of the dental arcade. The one mentioned first represents a rather aged individual and the second a young one. This young individual is more reliable for a correct reconstruction of the arcade than the likewise young B I because the dentition proves that B V is much older than B I in which the permanent dentition is not so far advanced (p. 15).

Compared with the reconstruction of jaw C made by Davidson Black the bicondylar breadth of my reconstruction is about the same: Black 148 mm, Weidenreich 146 mm. On the other hand the length of the jaw is different, namely the length measured from the labial surface of the medial incisor to the middle of the frontal plane touching the posterior borders of the condyles. This length is 105 mm in Black's reconstruction against 112 mm in that of mine.

There is no doubt that the figure given for the bicondylar breadth is very high, especially when compared with the same measurement of other hominid mandibles.

Sinanthropus jaw G I	148 mm
La Chapelle-aux-Saints	147.5
Krapina I	147.0
Heidelberg	131.0
Le Moustier (juvenile)	132-133

In the cases of La Chapelle-aux-Saints and Le Moustier the skulls pertaining to the jaws are available so that the relation between the bicondylar breadth and the breadth of the skull base outside the mandibular fossa can be calculated. The biauricular breadth cannot be taken as a measure of the skull base, this breadth being wider than the mandibular fossa breadth in *Sinanthropus* but narrower than that in Neanderthal man. In La Chapelle-aux-Saints the latter breadth is 152 mm, in Le Moustier (cast) 136 mm. As both brain case and jaw of Le Moustier, at least the casts which are at my disposal, are asymmetric I prefer not to refer to the relevant skull. Taking the skull of La Chapelle-aux-Saints as a standard the breadth of the brain case outside the mandibular fossa would be about 153 mm in the case of *Sinanthropus*. The breadth of *Sinanthropus* Skull I, the only preserved skull available for such a measurement, is approximately 136 mm. which is much less. But it must be taken into consideration that *Sinanthropus* Skull I is that of a child, probably not older than 9 years (compare Weidenreich, 1935).

In recent man the difference between the bicondylar breadth and that of the base of the brain case outside the mandibular fossa varies. The brain case is 3 to 10% wider than the mandible. The computed breadth of the base of an adult male skull of *Sinanthropus* of 153 mm is not at all extraordinary as is evident by comparing it with the breadths of the skulls of La Chapelle-aux-Saints (152 mm) and Rhodesia (148 mm).

b. Jaw H I (Plates XI-XV, fig. 2). The reconstruction of the mandible H I was much easier than that of jaw G I, the entire right half of the jaw including the symphysis being preserved. As the line of fracture of the left side runs in oblique direction from mesial above to distal below, the symphyseal part reaches in the region of the alveolar border beyond the middle of the left I_2 and at the basal border to the frontal plane of P_1.

The slightly damaged parts of the alveolar border of the mandibular notch and of the condyle can be restored without difficulty, the preserved parts serving as a secure basis for such work.

In the reconstructed jaw the bicondylar breadth amounts to only 102 mm, its length (measured from the "incision" — the teeth are missing — to the middle of the frontal plane touching the posterior borders of the condyles) is 107 mm.

The differences in size between G I and H I already mentioned above are still more pronounced in the restored specimens. This will be clearer by comparing the measurements of both jaws.

	bicondylar breadth	*length*	*symphysis height*	*condyloid height**
Jaw G I	148 mm	112 mm	39 mm	73 mm
Jaw H I	102 mm	107 mm	33 mm	63 mm

Jaw G I is to be regarded as representing an adult male and jaw H I as an adult female. The most astonishing feature of the latter, apart from the narrowness of the dental arcade, is the fact that the length of the jaw is greater than the breadth, a phenomenon which hitherto has never been observed in fossil or recent man but one which is characteristic for all monkeys and apes (compare below). In jaw G I the bicondylar breadth is much greater than the length. While the breadth-length index in the case of H I amounts to 104.8, the same index is only 75.6 in G I. With such an index G I falls well within the range of variation of recent man. Jaw G I has a greater bicondylar breadth than H I because its branches are longer. If one should make the reconstruction of G I to conform in its bicondylar breadth to that of H I, then the dental arcade would be too narrow to be in accordance with the idea we have today of the form of the hominid jaw. Since in the case of H I the exact shape and therefore also the bicondylar breadth is ascertained by preserved parts, I am not sure whether a correction should not be made in G I also toward narrowing the curve of the dental arcade.

c. Juvenile mandible B I (Plates XI-XV, fig. 3). Davidson Black made a dioptregraphic reconstruction of this jaw, the illustrations of which were published in his papers of 1933 and 1934. I made a plastic reconstruction of the same jaw. As the right side and the symphysis are preserved, the latter up to the line of the left canine, there remained for reconstruction only the left body and ramus which was carried out on the basis of the corresponding parts of the right side. As a basis for reconstructing the coronoid process completely broken off and of the condyle the uppermost part of which is rather damaged, I used the mandible F I. This specimen proves to be of the same age by the development of its M_1 and M_2. Both jaws differ only in size, mandible F I being larger and more robust as a whole and having a much bigger M_1 than jaw B I. As already stated above, I believe these differences to be due to sex; therefore jaw B I must be considered to belong to a female.

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* Measured with Hambruch's goniometer

It is very remarkable that the dental arch of jaw B I covers a much wider area than that of the adult jaws G I and H I. This corresponds to Black's reconstruction. Unfortunately there is no other mandible of exactly the same age preserved which could be used for comparison. But the mandible of B V, which approaches it although somewhat older according to the stage of its dentition, exhibits a narrower curve, a feature in correspondence with that observed in the adult mandibles. However, B V is obviously the mandible of a male individual judging by the size of its teeth. Whether that specific difference in the form of the dental arcade really depends on sex or whether it represents a mere individual variation, I do not venture to decide.

The bicondylar breadth of this jaw amounts to 108 mm, the length (incision as the anterior point of measurement) 88 mm, the height of the symphysis 27 mm and the condylar height 48.5 mm. The breadth-length-index is 81.3. The corresponding measurements of recent man of the same age are as follows:

Jaw specimen	bicondylar breadth	length	breadth-length-index	height of symphysis	condylar height
Rec. Chin. 44♂	109.0 mm	85.5 mm	78.9	21 mm	48 mm
Neol. " Kansu 404/11[*] ♀?	103.5 "	81.0 "	78.2	24.5 "	50 mm
" " " 157/7[*] ♂	107.0 "	74.0 "	69.2	23.(?)	42 mm
Sinanthropus B I	108.0 "	88.0 "	81.3	27.0	48.5 mm

IV. DESCRIPTION OF DETAILS

Before I describe the appearance of the mandible as a whole, I think it would serve for a better understanding first to give a description in detail of all the particularities of the specimens which have been used as a basis for investigation and comparison by all former students of fossil man.

For this purpose I divide the description of the mandible into separate sections defined by the general morphology of the bone and the special relief of its outer and inner surfaces. The sections in questions are enumerated and denominated in the table of contents so that it may be sufficient here to refer the reader to this list.

A. BODY OF THE MANDIBLE

1. The lateral surface.

(a) *Prominentia lateralis, area platysmatica*, etc. This region comprises the outer surface from the alveolar jugum of the canine to that point where the anterior border of the ramus meets the body and where the oblique line begins. Special attention was given to the lower part of this area by H. Virchow (1910, 1920). He found that in recent man the platysma is not attached to the lower border of the mandible as was believed formerly but that it crosses it and is inserted to the lateral surface of the bone itself. In connection with the attachment there are some peculiarities in the relief. H. Virchow called the whole area covered by this muscle the "planum platysmaticum." At times this planum is prominent and forms a "torus", and at other times it exhibits fine oblique and parallel striations running in the same direction as the fibers of the muscle — *striæ platysmaticæ* (H. Virchow). The platysmatic area is marked off from the body surface by a line — *linea platysmatica* (H. Virchow), which sometimes is deepened to a furrow—*sulcus platysmaticus*.

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[*] Somewhat younger than B I, M_2 is not quite in such an advanced stage of development.

According to Virchow the striations are not produced by the platysma alone but also by the fiber bundles of the triangular muscle which interlace with those of the platysma and adhere to the bone. H. Virchow supposed that the formation of the torus platysmaticus is an effect of muscle action.

This question is connected with another problem as, according to Virchow, the "linea platysmatica" sometimes terminates mesialward at a special protuberance which he called the "tuberculum platysmaticum" where the platysma is inserted by delicate tendinous fibers. Virchow identified this tubercle with the lateral tubercle of the mental protuberance and believed that the latter is also produced by the action of the platysma. This tubercle is known under different names in the literature: Klaatsch (1909) called it "tuberculum mentale posterius". Gorjanovic-Kramberger (1909) "tuberculum sub-mentale" and Toldt (1915) "tuberculum laterale." But according to Toldt this tubercle has nothing in common with the lateral tubercle of the mental protuberance which he named "tuberculum mentale." As I have already pointed out before (1934) care should be taken so as not to confuse the respective tubercles.

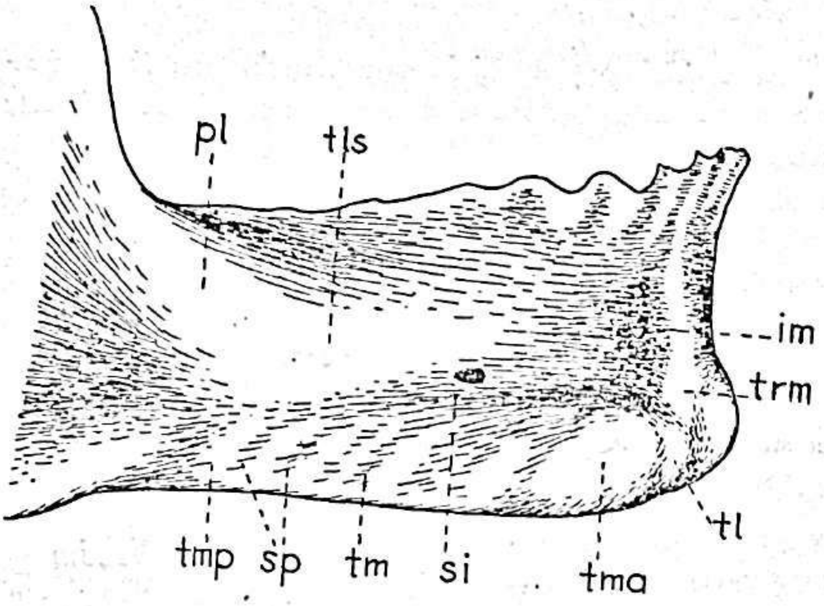


Figure I. Lateral surface of the body of a mandible of recent man (North Chinese No. 69) with well developed relief. Abbreviations:—im, incisura mandibulæ anterior, pl, prominentia lateralis; tl, tuberculum laterale; tls, torus lateralis superior; tm, torus marginalis; tma, tuberculum marginale anterius; tmp, tuberculum marginale posterius; trm, trigonum mentale; si, sulcus intertoralis; sp, striæ platysmaticæ. Natural size.

Textfigure I illustrates clearly the appearance of this region in those cases where the entire relief is well developed. The "area platysmatica" (*tm*) occupies the lower part of the outer surface and ends in a very distinct protuberance, the so-called "tuberculum platysmaticum" (*tma*). It is to be seen that the tubercle is clearly separated from the "tuberculum laterale" of the "trigonum mentale" (mental protuberance)—*tl*. The "striæ platysmaticæ" (*sp*) and the "sulcus platysmaticus" (*si*) are also recognizable as distinct formations.

It is important that in the great apes the platysma has no appreciable connection with the mandible running parallel to the jaw directly from behind to in front. According to van den Broek (1919/21) the triangularis muscle and the quadratus labii inferioris are likewise very poorly developed in monkeys and apes and do not attach to the bone or at best only to a small extent. On the other hand all the peculiarities of the outer lateral side of the mandible characterizing man are missing here. The whole field is smooth and equally rounded. Virchow's suggestion of a connection between the bone relief and the action of the mimetic muscles in man therefore really has a foundation, but Virchow himself doubted the possibility that such weak muscles as those mimetic muscles actually could produce such strong bony formations.

In order to decide this question it is necessary to study the entire lateral surface of the body. In a mandible with a well developed relief the most characteristic appearance is a very pronounced eminence where the anterior border of the ramus meets the body. Rasche (1913) called this eminence "prominentia lateralis." This eminence represents a strong reinforcement obviously caused by special trends of the bone which descend from the coronoid process (the attachment of the temporalis) and transfer the working point of this muscle to the body itself. The oblique line is nothing else but the continuation of the anterior border on the prominence. The posterior alveolar part deviates medianwards and is therefore separated from the upper part of the prominence by a more or less deep furrow which Keiter (1935) termed as the "sulcus extramolaris."

The prominentia lateralis extends downward to the lower margin. Towards the front it divides into two branches, an upper and a lower one. The upper one sweeps forward and comes to an end near the foramen mentale, while the lower branch occupies the entire lower margin. This branch is identical with the area platysmatica and terminates in the tuberculum platysmaticum. Both branches are separated by a more or less pronounced furrow-like depression: the sulcus platysmaticus. The prominentia lateralis itself and its direct continuation to the lower margin demarcate the lateral, slightly deepened, surface of the ramus to which the masseter attaches.

In this investigation I will use the following terms for the various formations. I shall retain Rasche's term *prominentia lateralis* but will call the upper anterior branch *torus lateralis superior* and the lower *torus marginalis*. The part of the prominence which reaches the margin and sometimes represents a distinct tubercle may be called the *tuberculum marginale posterius* and the tuberculum platysmaticum *tuberculum marginale anterius*. The furrow separating both tori may be called the *sulcus intertoralis*.

Of course there are many variations the degree of which depends chiefly upon the robustness of the mandible and the size of the prominence. In many cases the division of the prominence into two branches is only faintly indicated or the prominence passes almost completely into the torus marginalis (textfig. 2 *a*). In both cases the sulcus may be missing.

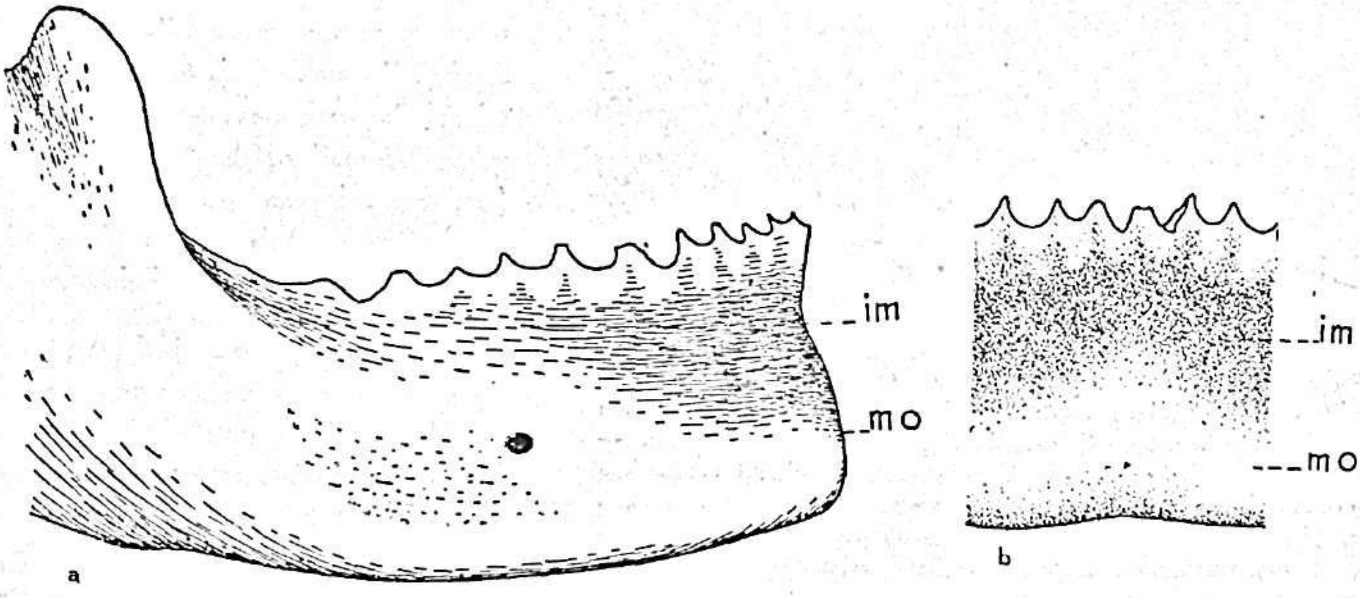


Figure 2. (a) lateral surface of the body of a mandible of recent man (Prehistoric Chinese — Kansu No. 404/6) with very weakly developed relief. Natural size. (b) frontal part of the same mandible with a distinct mentum osseum but without a clear mental trigonum. Abbreviations: — im, incisura mandibulæ anterior; mo, mentum osseum. Natural size.

In the medial surface of the body there is no eminence corresponding to the lateral prominence, but the alveolar part overlaps here considerably the lower margin. One could term this so-caused swelling *torus alveolaris*. The relief of the lateral surface therefore appears to be quite independent from that of the lateral surface, and could have been produced for the purpose of forming a reinforcement for the action of the temporalis on the body of the mandible. In many cases the prominence seems to be even more raised by the deepening of the attachment area of the masseter. This part of the ramus is sometimes formed by only a thin bone plate with thicker borders as a frame. The presence of thinner bone in parts where the muscle attachments occupy a great area is very common and characteristic for the skull. Here this is found in the region of the neck muscles and in that of the origin of the temporalis. The thickening of the bone itself takes place here only at the borders of the muscle fields; in the great apes the well known crests form the frames for them. A real thickening and strengthening of the bone substance is restricted to such points where static and dynamic conditions make it essential; this very seldom occurs in the proper fields of muscle attachments.

Viewed from this standpoint the prominentia lateralis and the tori, especially the torus marginalis cannot be produced by any direct action of mimetic muscles. The lateral prominence has never been considered in such a relation, obviously because no muscles attach here. But the torus marginalis of recent man was considered to be the effect of direct muscular action because the platysma, triangularis and quadratus labii inferioris come into contact with it (H. Virchow — tuberositas and torus platysmaticus).

A comparison with the mandible of the anthropoids may facilitate the decision of the question (textfig. 3). In gorilla, orang, and chimpanzee the appearance of the lateral surface is about the same. A lateral prominence exists and also indications of a division in two branches. Frequently in gorilla and orang males the torus marginalis (*tm*) and in particular its posterior tubercle is well developed and more or less distinct.

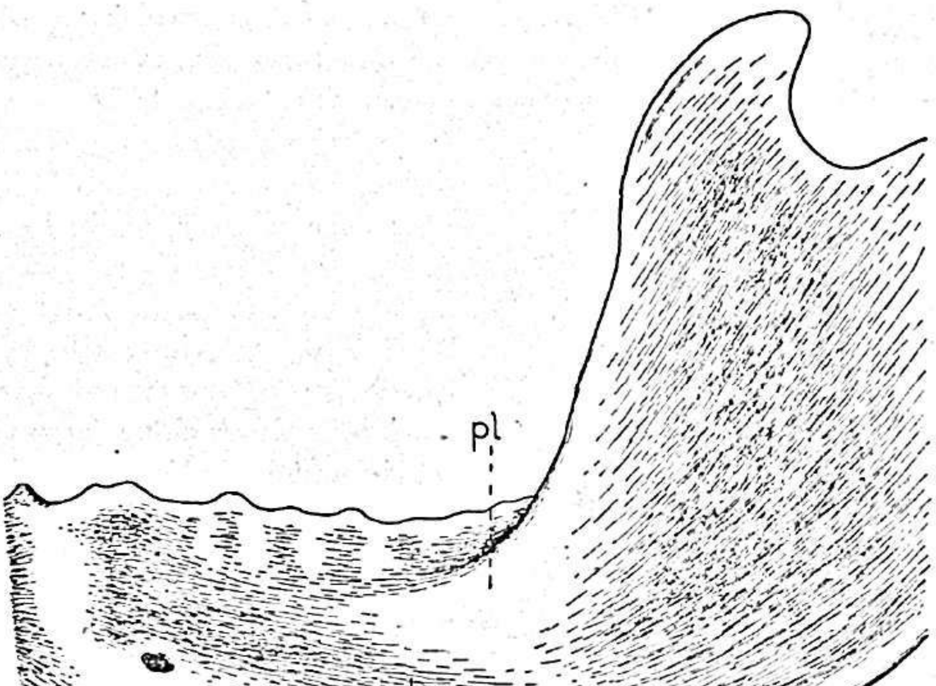


Figure 3. Lateral surface of the mandible of an adult male gorilla (No. 322). ×2/3. Abbreviations: — pl, prominentia lateralis; tm, torus marginalis; tmp, tuberculum marginale posterius; si, sulcus intertoralis.

In contrast to this a tubercle on the anterior end of the torus marginalis is missing in all three anthropoids, the torus being in direct connection with the very strongly developed alveolar jugum of the canine. The variation of the relief is not less than that in man, but viewed as a whole the eminence and the tori are stronger and have greater tendency to fuse with each other than is true in man.

Bluntschli (1929) called attention to the fact that in old male orangs a tuberculum platysmaticum is very pronounced and that a considerable portion of the platysma fibers attaches here. He brings this muscle loop into connection with the air-sac and the cheek-pads of the orang and believes that it may serve as some sort of a support for them. Bluntschli also remarked that a similar tuberculum is found in the Heidelberg jaw and he therefore considers the possible existence of those peculiarities in the soft parts of the Heidelberg man.

I have discussed elsewhere (1934) this particular question. In orang the tuberosity described by Bluntschli is situated rather backward and almost completely at the basal margin of the mandible, while the platysmatic tubercle considered in connection with the platysma by H. Virchow is situated at the lateral surface and near the mental protuberance. However, one should distinguish between a rough point of muscular attachment and the formation of a torus in the case of orang. The platysma fibers may produce a more or less circumscribed tuberosity but they are not able to produce such a thickening and swelling of the whole bone as is evident in the lowest part of the jaw. Incidentally, a rough spot may at times be observed in male gorillas in the same region.

Taken as a whole, it seems evident that the torus marginalis and its special differentiations, the posterior tubercle in man and apes and the anterior one in man, are not dependent upon or formed by a direct action of the mimetic musculature, for the torus exhibits the same robustness in apes as in recent man and in the former these muscles in no way come into contact with the bone with the exception of a small portion in orang as mentioned above.

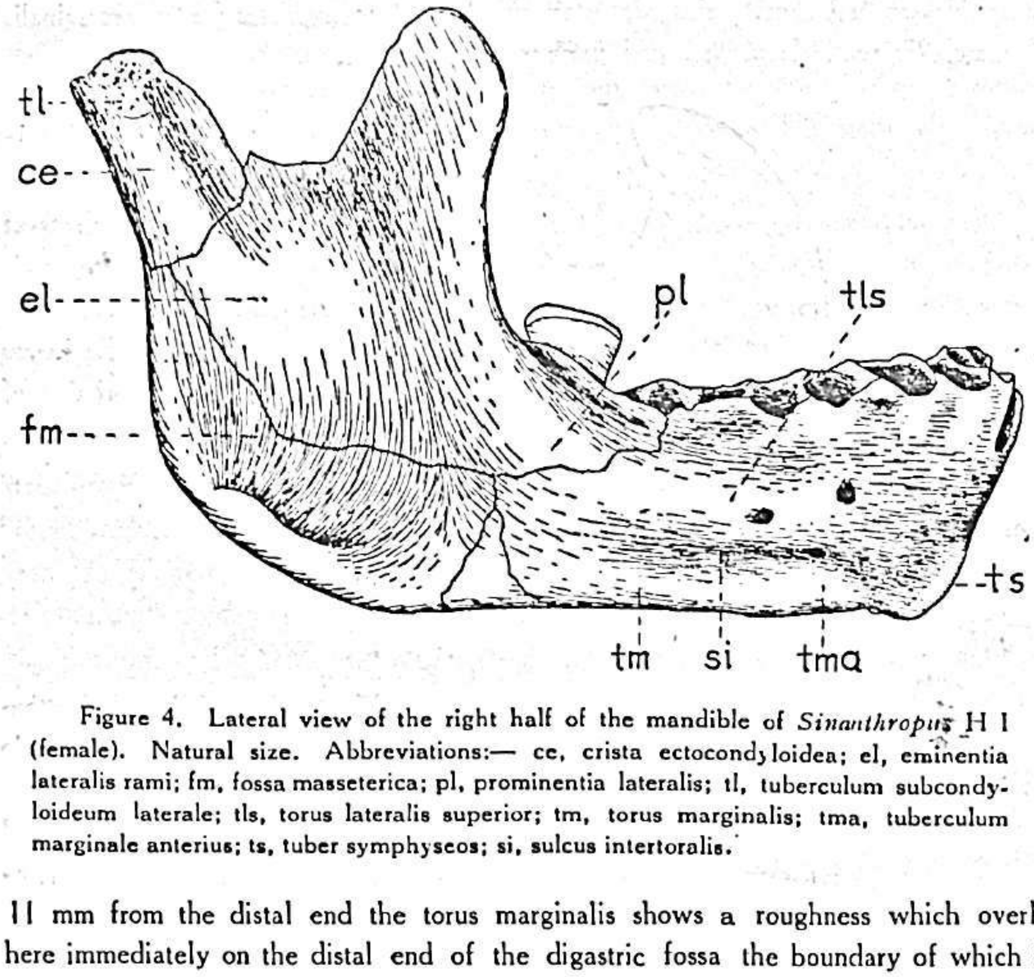


Figure 4. Lateral view of the right half of the mandible of *Sinanthropus* H I (female). Natural size. Abbreviations:— ce, crista ectocondyloidea; el, eminentia lateralis rami; fm, fossa masseterica; pl, prominentia lateralis; tl, tuberculum subcondyloideum laterale; tls, torus lateralis superior; tm, torus marginalis; tma, tuberculum marginale anterius; ts, tuber symphyseos; si, sulcus intertoralis.

The special appearance of the Sinanthropus jaws. H I is the best preserved jaw in this respect (textfig. 4, Plate VII, fig. 1). The anterior border of the ramus proceeds to a very distinct prominentia lateralis (*pl*). This prominence extends to the lower margin on one side and divides into two branches on the other. The upper one, the torus lateralis superior (*ts*), is very strongly developed and ends on the jugum of the carine; the lower one, the torus marginalis (*tm*), is also well-formed and ends in a distinct elongated anterior tubercle (*tma*), while a posterior tubercle is not clearly marked. The sulcus intertoralis (*si*) is an appreciably deep furrow. At a distance of about 11 mm from the distal end the torus marginalis shows a roughness which overlaps to the basal surface and borders here immediately on the distal end of the digastric fossa the boundary of which is formed by a fine irregular line. This roughness also extends to the lateral surface of the torus up to its mesial end and to the bottom of the sulcus intertoralis. But a distinct striation like that found in recent man does not exist, not even an indication of it, though the whole bone surface of this region is excellently preserved.

In G I (Plate IV, fig. 1) the relief of the lateral surface is much less differentiated than in H I. This may be in consequence of the much greater robustness of the jaw as a whole. The anterior border of the ramus proceeds here also to a well developed prominentia lateralis. From this prominence the torus superior runs forward and disappears near P_2. The prominentia lateralis extends to the lower margin but a distinct tuberculum marginale posterius does not exist nor does the torus marginalis itself rise to any extent above the general surface.

From the level of M_1 onward there is a shallow depression which marks the place of the sulcus intertoralis. But the anterior end of the torus marginalis represents a real and distinct swelling though not as large as could be expected from the size and robustness of this mandible (m). The whole surface of the torus marginalis is rough, this roughness overlapping to the basal surface and bordering upon the distal part of the digastric fossa. As in the case of H I this roughness also extends to the site of the sulcus, but a striation like that observed in recent man is not recognizable.

In A II (Plate I, fig. I) the ramus or at least its anterior border is not preserved but there is an indication of a faint prominentia lateralis. The torus lateralis superior is also indicated. The sulcus is more distinct. The torus marginalis is broken off with the exception of its merial end which is represented by a well developed tuberculum marginale anterius the surface of which is rough and adjacent to the smooth digastric fossa (*m*).

The conditions of the lateral surface in H I and A II are about the same. They contrast to those of G I in being much less developed in the latter. But as I have mentioned above, jaw G I as a whole is higher, thicker and more robust than the other. The same differences are also found in recent man so that one may deduct that the more robust a jaw is as a whole, the less the relief of the lateral surface is marked. In the case of *Sinanthropus* I believe firmly that these differences are due to sex. G I belongs to a male individual, H I and A II to female individuals.

This seems to be contrary to the impression given by the Heidelberg mandible notable for its robustness of the lateral relief which is the same as in the *Sinanthropus* females, but from this fact I do not dare to draw the conclusion that the Heidelberg fossil also belongs to a female, although its teeth are strikingly smaller than those of the two female *Sinanthropus* jaws. However, the Heidelberg jaw in no way differs in the general appearance of the lateral relief from the mandibles of the Neanderthal group, as for instance from Krapina (H and I) and Ehringsdorf (adult).

In regard to the jaws of this latter group the three mentioned above come very close to the one known as *Sinanthropus* H I; the differences being such not worth mentioning. The Heidelberg jaw shows the same characteristics with the exception that the tuberculum marginale anterius appears to be stronger than in the cases of Krapina and Ehringsdorf. However, this phenomenon is not dependent only upon a real stronger formation of the tuberculum itself but also upon the fact that the basal border of the Heidelberg jaw is bent upward just beyond the tubercle to form the so-called incisura submentalis (compare below). The tubercle therefore projects further than would be the case if this curvature did not exist.

I believe that from a morphological standpoint the Heidelberg jaw has been interpreted incorrectly. The various investigators permitted themselves to be deceived by the size and robustness of the body and ramus and therefore considered this specimen to be more primitive than all the other jaws known so far, including the entire Neanderthal group. However, as I have demonstrated recently (1936 *b*) the characteristics of the dentition of *Sinanthropus* on one hand and those of the Heidelberg Man on the other prove that there is a fundamental difference between these fossils, the former being a really primitive one, while the latter is closely related to that of the Neanderthal group, representing a special type.

The relief of the lateral surface of the *Sinanthropus* female mandible therefore corresponds to the general appearance of that of the Neanderthal group, while that of the *Sinanthropus* male is much more simple and exhibits a much more pithecoid character. But I wish to point out that the same differences of the relief may also be found in recent man. With the exception of the special feature of the tuberculum marginale anterius more pronounced because of the presence of an incisura submentalis the relief of the Heidelberg jaw does not differ fundamentally from that of recent man with a well developed relief. The same is true for *Sinanthropus*, the only difference being the deepness of the sulcus intertoralis and the absence of any striation on the surface of the torus marginalis. This question will be discussed later.

The juvenile jaws of *Sinanthropus* show various differences when compared with those belonging to the adult individuals. Jaws B IV and B V are badly damaged in this particular region which is also true for B III. In jaw F I only the posterior part is preserved. Jaw B I is therefore the only specimen on hand which may serve as a reasonable basis for description and comparison, although objections might be made on account of its being badly damaged and having been subsequently restored by Davidson Black (Plate II, fig. 1). Nevertheless, some facts are obtainable. The prominentia lateralis is well developed, but corresponding to the age of the jaw this prominence is situated at the level of the last molar, that is to say, on the labial side of the first permanent molar. Both tori and the sulcus intertoralis are only faintly indicated, the whole region projecting more or less on account of the germs of the permanent teeth being embedded in this part of the jaw.

Jaws of recent man of corresponding age reveal more details. This holds good especially for the torus marginalis the development of which may be in connection with that of the symphyseal part of the jaw. I will refer to this later.

(b) *Foramen mentale.* It is not quite correct to speak of a foramen mentale in *Sinanthropus* because none of the specimens preserved show just one single foramen. The multiplicity of this aperture is a rather striking characteristic feature of *Sinanthropus*.

In jaw G I (Plate IV, fig. 1) there are five apertures. These are arranged around an oval slight eminence which is situated immediately at the anterior end of the torus lateralis superior in level with the interalveolar septum of P_1 and P_2. The five foramina are almost of the same size. The distance between the foremost and the last is about 10 mm, that between the uppermost and the lowest about 9 mm. Both the last and lowest openings are directed backward, the foremost forward and the fifth upward and slightly backward.

In jaw A II (Plate I, fig. 1) a joint area does not exist. The apertures, four in this case, are situated along a curve the convexity of which is directed forward and downward. The focus of this curve is in the level of the anterior root of M_1 and at a distance of about 10.7 mm from the lower margin and of about 14.0 mm from the alveolar border. One of the four foramina is large, its mesio-distal diameter being 2.8 mm, the three other ones being much smaller, in fact one of them is very small. Three of the foremost apertures are situated above each other in the mesial region of P_2, the lowest one being rather removed distally and situated in the level of the posterior border of the root of M_1. The uppermost is at a distance of 7.5 mm from the alveolar border, the lowest about 6.5 mm from the lower margin which is damaged at this point. The large foramen faces directly outward, the last and the uppermost and the smallest directly backward and downward.

In jaw H I (Plate VII, fig. 4) there are three apertures. As in the case of G I these foramina are arranged around a circular thickened area lying at the torus lateralis superior and sloping upward against the alveolar part and downward against the sulcus intertoralis. This area is located just below the septum between P_2 and M_1. All three foramina are at a distance of about 4.5 mm from the center of the area. One aperture, the larger one, is situated in front and slightly higher; the smaller one behind and slightly lower and the smallest one lowest in relation to that center. The aperture of the anterior foramen faces downwards, that of the posterior and the inferior ones backwards. The lowest foramen is at a distance of 7.2 mm from the lower margin, the center of the uppermost is 12.4 mm away from this margin.

In regard to the juvenile jaws only B I, B III and B IV allow a statement with respect to the foramina. For B I (Plate II, fig. 1) Davidson Black reported the presence of at least two apertures. Unfortunately, this particular region is badly damaged and its entire surface so uneven that it is difficult to recognize the fine relief. It is certain that there is one large foramen. This foramen is situated in line with the distal part of m_1 and is appreciably elevated, that is to say, about 12.8 mm above the lower margin. Approximately 6.5 mm further in a distal direction, in line with the mesial part of m_2, there is a small impression which may represent a second foramen, but it is impossible to prove with any degree of certainty whether additional apertures existed.

In jaw B III (Plate VIII, fig. 8) three apertures exist. As in the case of jaw A II they are situated around a slightly elevated center along a curve the convexity of which is directed forward and downward. The main aperture is mesial to this center in line with the distal border of the mesial root of m_1. Above and slightly more mesially there is a second small aperture. The third one is of about the same size as the second aperture and is situated in almost the same horizontal line as the latter but more than 9 mm. in a distal direction and in line with the mesial root of m_2. The upper foramen is about 7 mm away from the upper alveolar border, the large one about 11 mm and the third one about 9 mm from the lower margin. The middle aperture faces directly outwards, the upper is directed upward and the third backward.

In B IV (Plate VIII, fig. 3) at least two apertures must have been present. As the border of the mandible is broken off immediately below the apertures, it is possible that one or more were situated in the parts missing, the anterior one of the two apertures being located just at the damaged margin. Both apertures are of about the same size, namely small and give the impression of being accessory. The posterior aperture lies in line with the distal border of m_1, the anterior one in a horizontal distance of 6.6 mm from the posterior opening. The distance of the anterior aperture from the alveolar border is 12 mm, that of the posterior 10 mm. The posterior aperture faces backwards and downwards, the anterior one directly outwards.

A comparison with the jaws of the Neanderthal group yields the following result. The right side of the Heidelberg jaw with its three foramina resembles closely *Sinanthropus* jaw A II in respect to the size and arrangement of the three anterior apertures. The left side of the Heidelberg shows only two foramina, a large one and a much smaller one. Among the Krapina material the right side of jaw G corresponds in general to that of *Sinanthropus* H I in regard to the number, size and arrangement of the apertures. A circular eminence like a center around which the foramina are grouped also exists. This is true for the Krapina I—right side—where only two apertures are present which are located before and behind a distinct swelling. According to Boule (1912) the jaw of la Chapelle-aux-Saints shows two joint foramina on the right side separated only by a narrow bone bridge. According to this author the same peculiarity is found in the jaws of La Naulette, d'Arcy, Malarnaud and Spy I.

One of the most remarkable facts observed in *Sinanthropus* jaws is the multiplicity of the mental foramen. According to Simonton (1923), to whom we are indebted for the best comparative investigation on the occurrence of the mental foramen, four or five foramina have never been found in recent man regardless of race. Three foramina are known to occur in 0.19% and two in 4.3%. Akabori (1933) likewise never observed the occurrence of four or five foramina in the Japanese material he investigated, but he found three foramina in 0.73%, and more than one in 3.7%.

In the *Sinanthropus* material there are six specimens available the numbers of the apertures of which are as follows:

Number of apertures	Specimen	Number of jaws
5	Jaw G I	1
4	Jaw A II	1
3	Jaws H I and B III	2
2	Jaws B I (?) and B IV	2

Within the Neanderthal group the Heidelberg jaw (at least the right side) and the Krapina jaw G also show three foramina.

According to Simonton the occurrence of the multiplicity of foramina in anthropoids is as follows:

Species	Number of apertures	percentage	more than two apertures
Gorilla	3	7.2%	14.4%
Gorilla	2	7.2%	
Orang	4	0.8%	39.0%
Orang	3	5.7%	
Orang	2	32.5%	
Chimpanzee	3	3.1%	15.6%
Chimpanzee	2	12.5%	

This list seems to testify that the multiple occurrence of the foramen observed in *Sinanthropus* and within the Neanderthal group is a genuine pithecoid character. The latter is particularly pronounced in *Sinanthropus* where the occurrence of more than one foramen is ascertained in 100% against 4—5% in recent man.

However, it is to be noted that there is a difference between *Sinanthropus* and the anthropoids. In all anthropoids where I observed more than one aperture I found that one foramen was much larger than the remaining ones and that the latter had the character of being accessory apertures always located far in front of the main foramen. In comparison with the forms belonging to the Neanderthal group it may be stated firstly that the multiplicity of the apertures always occurs in *Sinanthropus*, while within the former group it occurs to a large percentage, and secondly, that more than three foramina have never been reported to occur in the Neanderthal group.

Bünte and Moral (1910) and Schulz (1933) state that the apertures are directed backwards and at the same time upward in by far the majority of cases in recent man, while in anthropoids they are directed forward. This latter statement is not quite correct for in some cases the apertures are also directed backwards or upwards.

As stated above the direction varies in the individual cases of *Sinanthropus* so that the backward direction cannot be considered as representing a rule.

It is difficult to understand the reason underlying the multiplicity. In any case it is remarkable that when more than two apertures exist, they are always arranged around a center forming a circle or a curve with a convexity directed forward. The center slightly projects beyond the surrounding surface so that the impression is given that the main distribution of nerves and blood vessels which takes place in recent man immediately after emerging from the foramen occurs in *Sinanthropus* within the mandible itself and directly under that eminence, which in this way forms a sort of cover under which the already distributed vessels and nerves spread into various directions and emerge through several apertures.

As to the position of the mental foramen the figures for recent man given by Simonton show that there is no fundamental difference between *Sinanthropus* and recent man, the foramen lying most frequently in line with

P_2 or the septum between P_2 and M_1. In the case of *Sinanthropus* it will be realized that the center just mentioned is taken as an indicator for the exact location of the proper foramen.

2. The anterior (labial) surface of the frontal part: mentum osseum — trigonum mentale — incisura submentalis — incurvatio mandibulæ anterior.

The part of the mandibular body discussed in this paragraph embraces the area between the alveolar juga of both canines. As in recent man its character is influenced by the chin which will be discussed first in the following description.

The term "chin" (mentum) commonly used for the basal prominence in recent man actually comprises two different phenomena which should be distinctly differentiated. In my first publication on the chin (1904) I called attention to this fact, but nevertheless it was neglected by most of the investigators interested in the problem dealing with the chin. Thirty years later (1934), when making new comparative investigations on a much larger scale, I was able to prove that my first standpoint was correct.

The two different features to be distinguished are: (1) the projection of the entire median and basal part of the frontal mandibular section beyond the adjoining regions; and (2) the accentuation of this projection by the first mentioned formation "mentum osseum" and the second one "trigonum mentale." The latter formation corresponds to the mental protuberance proper which H. Virchow (1920) proposed to designate as the trigonum mentale. The fact that both formations when viewed from the descriptive standpoint are entirely independent from each other is proven by the incidental occurrence of a distinct mentum osseum without an indication of a trigonum mentale. Textfigure 2 *b* represents such a case; the alveolar part of the frontal section here is separated from the basal part by a continuous uniform depression. The whole basal part appears in the form of an equally rounded swelling.

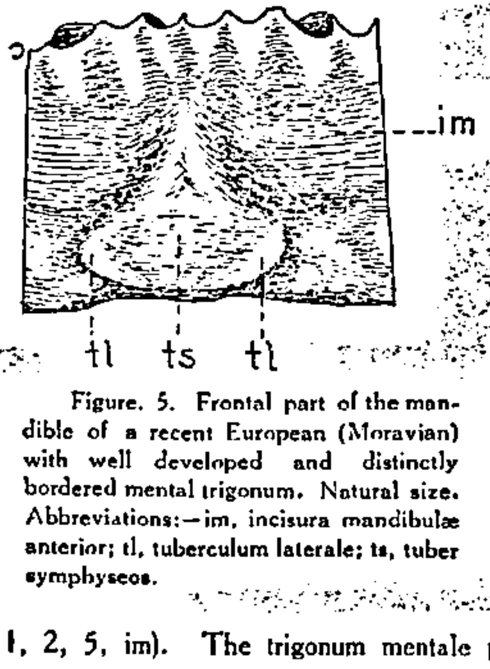


Figure. 5. Frontal part of the mandible of a recent European (Moravian) with well developed and distinctly bordered mental trigonum. Natural size. Abbreviations:—im, incisura mandibulæ anterior; tl, tuberculum laterale; ts, tuber symphyseos.

The well developed trigonum mentale (textfig. 5) consists of a triangular eminence. Its base corresponds approximately to the lower margin of the jaw and its vertex comes to lie in the middle line of the space between the alveolar juga of both medial *I*. The trigonum itself usually is much more pronounced in its middle part. The latter eminence can be called "tuber symphyseos" (*ts*) for it conforms to the symphysis of the jaw. The basal corners likewise are often thickened, sometimes to very distinct tubercles which represent the so-called *tubercula lateralia* (*tl*). In certain cases one may also find that the middle of the triangular basis is not at all prominent but may even be deepened.

The more or less circular depression which separates the basal part of the frontal section from the more prominent alveolar border and thereby causes the projection of the basal part, which is the mentum osseum, has been called by H. Virchow (1920) the *incurvatio mandibulæ anterior* and by Klaatsch (1909) impressio incisiva (textfigs. 1, 2, 5, im). The trigonum mentale projects beyond the bottom of this general depression with its greater part so that the deepening is mostly divided into a right and a left half.

The most essential formation causing the projection of the mentum osseum is that depression. In this regard it is of no significance whether the alveolar border protrudes further forward than the basal border, as is true in the case of prognathism or, whether the basal part is more prominent than the alveolar one as in the case of orthognathism. The so-called "positive" and "negative" chins (Klaatsch) show the same character in regard to this aspect.

In all monkeys and apes the alveolar border projects much further forward than the lower margin of the jaw and the depression in question — incurvatio mandibulæ — is missing (textfig. 3). A mentum osseum therefore does not exist in this particular group of primates, and hence it shows a real prognathism.

The question whether *Sinanthropus* possesses a chin or not was answered by Davidson Black by the assertion that a mental prominence was "completely absent" (1929). He reached this conclusion by his observations on the juvenile *Sinanthropus* jaw B I. However, Black overlooked the fact that the term "mental prominence" is as ambiguous as the term "chin" because it does not define distinctly between "mentum osseum" and "trigonum mentale."

Thus the question arises as to whether *Sinanthropus* had a chin. According to my understanding it should be determined whether there exist an incurvatio and a trigonum mentale or whether only one of these features is present or none at all. As a basis for such determination jaws H I and H IV are available as representing adult individuals and B I and B V as those of juvenile individuals. Since the basic parts of jaws B V and H IV are badly damaged or broken off, only H I and B I can be used in this particular instance. In H I the whole region in question is preserved with the exception of the upper distal part of the left side.

As is evident in the illustration (textfig. 4, and Plate VII, fig. 4; Plate VII, fig. 1; Plate XI, fig. 2) of the preserved parts if the mandible H I and from the reconstruction derived by correct orientation to the alveolar plane, the alveolar border of the frontal part projects and its basal margin falls back. However at the same time the side view shows that a clear depression which would indicate a real incurvation between the alveolar and the basal part does not exist. Nevertheless a faint indication of a flattening between both regions is recognizable.

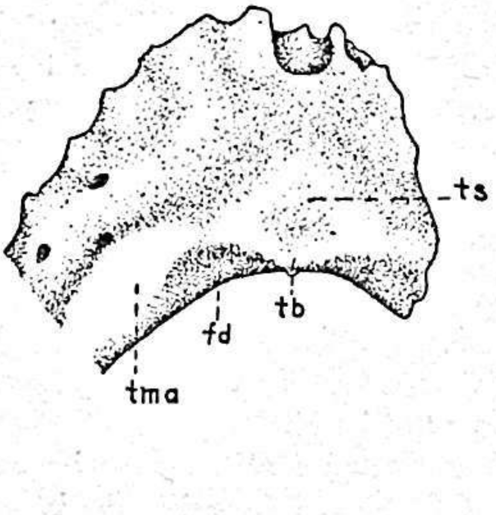


Figure 6. Frontal part of the mandible of *Sinanthropus* H I (female) in frontal and lower view. Natural size. Abbreviations:— fd, fossa digastrica; tb, trigonum basale; tma, tuberculum marginale anterius; ts, tuber symphyseos.

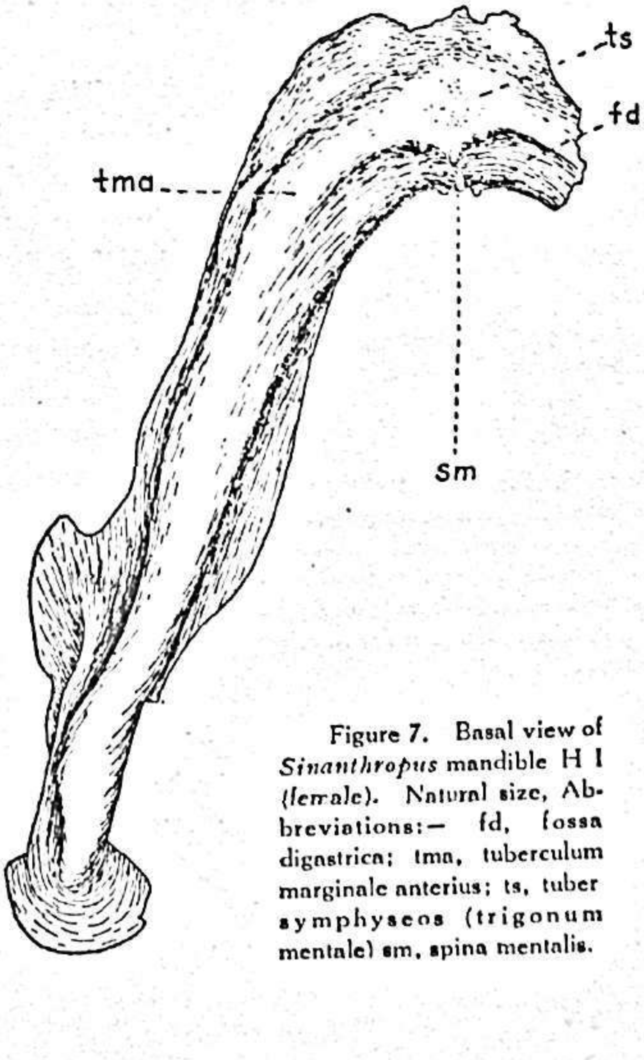


Figure 7. Basal view of *Sinanthropus* mandible H I (female). Natural size, Abbreviations:— fd, fossa digastrica; tma, tuberculum marginale anterius; ts, tuber symphyseos (trigonum mentale) sm, spina mentalis.

Therefore, it cannot be doubted that a genuine mentum osseum is absent. In the case of the trigonum mentale the situation is different, for in the regions of the latter formation an appreciable swelling is to be observed, especially by palpation (textfig. 6). Viewing this point from the basal side of the jaw (textfig. 7) one will note that the middle part slightly projects and flattens toward both sides. This prominence when viewed from the front is quite clearly triangular (textfig. 6 and Plate VII, fig. 5) even though its demarcation may appear to be rather vague. The triangular elevation is low and broad, and its base coincides with the lower margin. A distinct vertex is not recognizable. The lateral corners are not especially marked. As on the right side, the tuberculum marginale anterius is rather pronounced and slopes in mesial direction, the boundary between the corner and the tuberculum being quite indistinct. The special appearance of the basal line of the trigonum will be discussed in a separate chapter in connection with the "incisura submentalis" (compare below).

The trigonum mentale of H I, that is to say, the eminence in the basal region of the symphysis, corresponds to the trigonum mentale which in 1934 I proposed to call "tuber symphyseos." Its highest elevation is found within a distance of 24 mm from the incision. Below this point the trigonum flattens to a broad, oval and faint depression of about 6 mm in length and 4.5 mm in breadth. This depression is rather sharply defined in the median line and at the point of declivity to the marginal border. The height of the trigonum measured in the median line is 16 mm, the breadth of the base from the median line to the mesial end of the right tuberculum marginale anterius about 13 mm, and the whole breadth about 26 mm.

The presence of a trigonum mentale in jaw H I is certain and it can be further verified in the juvenile B I (textfigs. 14 and 53; Plate II, figs. 5, 6; Plate VIII, fig. 1). In the latter the symphysis is also well preserved and thus permits a reliable determination. While in jaw B I a mentum osseum or any other delimitation between alveolar and basal part of the front is missing entirely, a triangular elevation in the median line is distinctly visible.

The main part is represented by a blunt edge which begins at about 11 mm below the alveolar border and courses, broadening gradually, accurately along the median line. The lateral borders of the swelling stand out against the adjoining surface by a clear flat depression and continue with the lower margin without any distinct lateral elevation (Plate VIII, fig. 1). The height of the entire prominence is about 11 mm and the breadth at the base about 18 mm. As is true in H I there also exists in B I a flattening of the lowest part of the swelling just in the middle line and slightly above its lower border.

The trigonum mentale in *Sinanthropus* corresponds to that of recent man with respect to its position and its general form. It differs from the latter by its lowness, its indistinct delimitation between the adjoining parts and the complete absence of the lateral tubercles.

The flattening of the triangular eminence in the middle of the lower part deserves special note. Before discussing this phenomenon, it may be well to call attention to two other features of the mandible which concern more particularly the lower border but nevertheless are also in close relation to the region under discussion. These phenomena are the so-called incisura submentalis and the trigonum basale.

In the Heidelberg jaw the lower margin of the symphysis is strongly bent upward so that it presents an appreciably high and wide arch. Klaatsch (1909) called this formation "incisura submentalis." According to H. Virchow (1920) this arch should be considered characteristic for hominids of an early diluvial period as he failed to observe them in anthropoids and ascertained its occurrence in recent man in exceptional cases. In the Neanderthal group the incisura is very pronounced in the mandible I of Krapina and in that of Spy I. H. Virchow drew attention to the fact that in consequence of the deepening of both digastric fossæ located at the lower margin in the area of the arch, the tuberositas interdigastrica which separates both digastric pits projects markedly. The submental notch thereby assumes the form of a Cupid's bow comparable with the edge of the upper lip in the region of the philtrum. In other words the submental notch is not a single and equally curved arch but one divided into two symmetrical parts by a median and downward directed prominence which corresponds to an interdigastric spine.

I do not believe that the significance of the incisura submentalis will be known correctly if the interpretation is restricted to this formation. The Heidelberg jaw shows clearly that the submental notch is nothing else but the median of three larger inlets of the lower mandibular border, the other two being represented by the preangular curvatures of the rami.

On the other hand this appearance of the lower margin of the jaw can also be described as projecting downward in marked degree between the symphysis and the rami, which would mean, that not the incisura submentalis but the downward projection of both halves of the body constitutes the essential characteristic of the outline. This projection corresponds exactly to the torus marginalis described above. In the case of the Heidelberg jaw the torus is strongly developed and therefore does not only protrude sidewards but also downwards. In other words, the degree of the formation of the submental notch depends greatly upon that of the torus marginalis, especially upon its anterior part. Thus the depth of the notch has no relation whatever with the height of the symphysis or any other particularity of the median part.

Virchow's assumption that the incisura submentalis is absent in anthropoids is only correct in so far as this term and what it is founded on is taken literally. In some cases in orang as well as in gorilla the lower margin of the mandibular symphysis terminates with a more or less prominent spine while the margin on both sides of it is clearly curved. Beyond these curvatures the lower border is thickened and projects as a result of the strongly developed torus marginalis and its tuberculum marginale posterius. The basal curvatures of anthropoids and those of the Heidelberg jaw (incisura submentalis and tuberositas interdigastrica respectively) differ in principle only with respect to the direction of the curves. In anthropoids the latter are directed backwards on account of the marked inclination of the whole frontal part while in the Heidelberg jaw the curves bend downwards, the front part being more erect here.

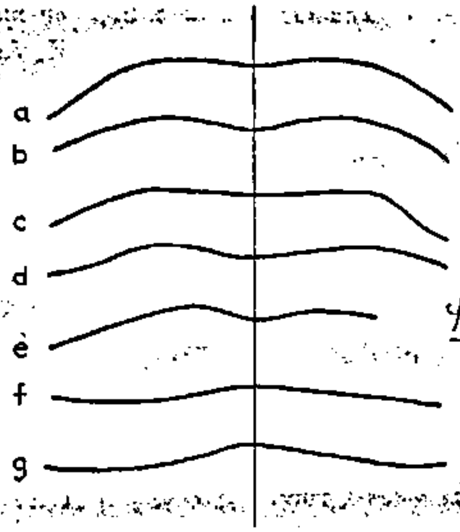


Figure 8. Outlines of the lower margin of the symphysis. Natural size. Designations:—a, Heidelberg; b, Krapina I; c, Ehringsdorf adult; d, Spy I; e, *Sinanthropus* H I; f, recent North Chinese (No. 159); g, recent European (Moravian).

Sinanthropus serves as a good example when studying the conditions of this region in a primitive hominid type. In jaw G I, although the symphysis is not preserved, there is evidence that a distinct notch directed towards the mesial line from the tuberculum marginale anterius had existed. In Plate IV (figs. 1 and 2) the outline of the lower border of the left side rises distinctly from that point. In jaw H 1 the whole part in question is preserved. At first sight an incisura submentalis seems to be absent but on closer examination one finds the same formation as in the Heidelberg jaw (Plate VII, fig. 5 and textfigs. 4, 6). H I differs from the latter only in regard to the arch which is flat and the projecting interdigastric portion that occupies a large space. The juvenile female jaw B I corresponds completely in this respect to the adult H I (Plate II, fig. 7 & Plate VII, fig. 2) and the same holds good for the juvenile male jaw B III in which only the right half of this region is preserved (Plate VIII, fig. 8).

Viewed from the comparative standpoint, the occurrence of the symphyseal spine and its pronounced prominence in *Sinanthropus* is more important than the existence of the incisura, since the first mentioned formation is to be found in the same area and equally developed in anthropoids, only, as just stated, it takes a different course. In recent man on the other hand the corresponding region, that is to say, the basis of the mental trigonum, offers an entirely different picture. Usually the outline of the symphysis does not project downwards but instead is more or less curved upwards, or it may also be even (textfig. 8).

The mandibles of the Neanderthal group in this respect approach those of *Sinanthropus*. In all the comparative material at my disposal the symphyseal spine is more or less developed in the Ehringsdorf, Krapina E, G, H, I; Malarnaud, Le Moustier, La Naulette, Spy, with the exception of La Chapelle-aux-Saints.

Textfigure 8 shows some of these characteristic outlines. In recent man the base of a well developed trigonum mentale (textfig. 5) is marked off from the lower margin by a rather straight line. Beyond this line the margin slightly falls back. Since in *Sinanthropus* jaw H I the mental trigonum represents but a faint eminence, it continues at the lower border so that the anterior margins of the digastric fossæ appear to form the lower limit of the trigonum (textfig. 7 *fd*). These fossæ being separated from each other by a small triangular area (compare below), which corresponds to the symphyseal spine just described, makes it seem as if the intervening area belonged to the mental eminence itself. In this way the latter derives its rhombic shape.

This particular feature of the *Sinanthropus* chin region resembles one sometimes found in juvenile jaws of recent man and also in those of anthropoids. Textfigure 9 illustrates the mental trigonum of a Chinese male child of about 3 to 4 years in age. This trigonum consists only of a tuber symphyseos similar to that of *Sinanthropus;* the lateral tubercles are not developed. On the other hand the trigonum continues with the interdigastric spine so that it assumes the rhombic shape. In a very young male gorilla (textfig. 10) in which the deciduous canines are just erupting and the suture of the symphysis is still patent except in its lowest part, there is a distinct median prominence just at the "chin" region, that is to say, above the anterior margin of the digastric pits which continues downward between the two pits. Further above and inward the prominence terminates in a sharp edge-like spine which projects backward.


Figure 9. Region of the chin of a 3-4 year old male North Chinese child (No. 50). Natural size.

The connection between the mental prominence and the interdigastric area in the cases of adult *Sinanthropus* and in juvenile stages of recent man and gorilla proves that the formation of the mental trigonum is the result of the special type of union of the halves of the mandible but one which is not directly dependent upon the development of the mentum osseum, that is to say, upon the most projecting basal part of the jaw. Another argument in support of the fact that the formation of the mental prominence in *Sinanthropus* is dependent upon the same process as in recent man is the existence of a small depression located immediately in the middle line and at the highest elevation of the swelling (textfig. 7). In juvenile mandibles of recent man this depression may be found to be clearly outlined as in the case of a jaw of a Japanese child of about 5 years (textfig. 11). The latter shows that the suture remained open in exactly the same place, and the depression corresponds to a slight folding inwards of the lower corner of the medial borders of both halves. In the same jaw the rhombic shape character of the mental prominence mentioned above and its extension to the lower surface is evident.

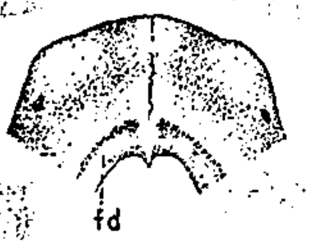


Figure 10. Region of the symphysis of a very young male gorilla child (No. 30) with traces of the suture and a carina-like prominence. Natural size. Abbreviation: fd, fossa digastrica.

As I demonstrated first in 1904 and then more in detail in 1934, the trigonum mentale is to be considered as a sort of gusset set into the symphyseal juncture between the two halves of the mandible in the inferior two-thirds of its height. This gaping is caused by the curvature of the anterior parts of the two halves in a frontal plane to form the front of the jaw. Primarily these halves were tapering like a rostrum and closely joined to each other throughout the whole height of the symphysis. They terminate in a curved line, the alveolar end projecting forward and the basal end falling back (textfig. 12a). In hominids the anterior parts of the halves are turned up toward the median line gradually to form a frontal plane. In the same degree as this turning becomes effective, the basal parts will separate more and more while the alveolar parts remain in contact. *In this way a triangular gap in the symphyseal juncture appears* which has to be filled by bony substance so as to secure and strengthen the juncture (textfig. 12b). In recent man where this gap has reached its largest extension this filling material consists of several small irregular and isolated bones bearing a sutural character. These are the so-called ossicula mentalia (Mies). We do not know in what stage of phylogenetic evolution these bones appeared. However, its first differentiation may have started in the *Sinanthropus* stage.

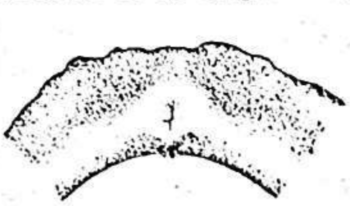


Figure 11. Mental trigonum in the stage of development in recent man (Japanese child of about 5 years) with the part of the suture still present and the median depression recognizable.

The appearance of the symphyseal gap is connected with another phenomenon which is not less important for the knowledge of the formation of the mental trigonum. In mandibles of very young children of recent man there is to be observed that the two halves of the jaw which bound the gap are raised and thickened (textfig. 13). This elevation gives rise to two pits, one on each side, at the corner of the jaw endings (*fm*). Toldt (1915) called these depressions fossæ mentales. A *comparison of the various stage of the individual formation of the trigonum mentale shows that the lateral borders of the triangular elevation represent nothing else but those thickened endings.* The lateral tubercles precisely mark the corners where the lower borders of the jaw turn to the median borders and reach the junction. The median depression at times also very evident in adult specimens designates the site of the original gap. In the juvenile jaw of *Sinanthropus* B I the triangular prominence corresponding to the mental trigonum of recent man reveals very distinctly the original significance of the chin relief. As is seen in textfigure 14 the two curved anterior halves united by the symphysis, the mental fossæ around which the curves course and the median flattening between these curves bounding the original gap (g) are recognizable even though only faintly indicated.

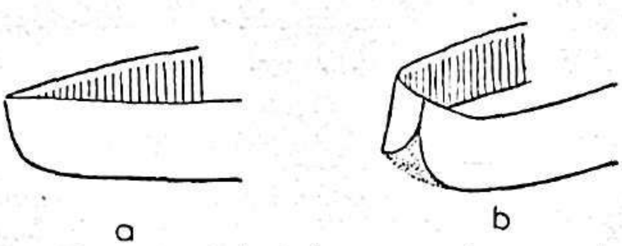


Figure 12. A sketch demonstrating the manner of junction of the two mandibular halves. Designations: (a) the original bow formation and (b) the bending in frontal direction with a gusset-like formation.

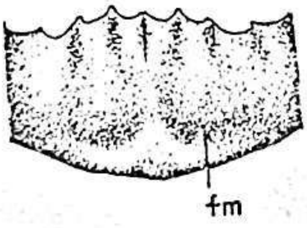


Figure 13. Mental trigonum of a 3-4 year old North Chinese child (No. 61). Natural size, Abbreviation:—fm, fossa mentalis.

All these facts combined prove that within the *Sinanthropus* group, the appearance of a trigonum mentale for the first time is realized.

It is of importance to know the details in this respect within the Neanderthal group. Most writers contend themselves with the simple statement that a chin is absent in the latter form. However, it is obvious that the matter in question cannot be settled by such a general remark. Here also a differentiation should be made between the features "mentum osseum" and the "trigonum mentale." With reference to the latter, Gorjanovic-Kramberger (1908/09) reported the presence of a "flat mental plate" in the Krapina mandibles G, H and I with a slight swelling in the case of jaw H and with faint spurs tapering laterally on each side in the case of jaw I. H. Virchow (1920) claimed that in the two Ehringsdorf mandibles the "tuber mentale" is recognizable as a rather faint roundish eminence not only palpable but also visible. As much as the casts will permit me to judge, I am able to confirm Virchow's statement. In this comparative study I found that the Krapina jaw I exhibits the same features as the jaws H I and B I of *Sinanthropus*: the triangular shape of the mental swelling, the outline of the lateral corners and the median depression associated with the interdigastric spine. With regard to the mandible of Spy, Hrdlicka (1930) states: "There is no chin eminence, yet there is a slight broad chin with a moderate depression above." This remark implies that a mental trigonum is here in the stage of development. Unfortunately, the mental region in the Heidelberg jaw is so badly damaged as to render it impossible to decide whether or not a trigonum was present. According to the cast it seems that a tuber symphyseos had existed (textfig. 54).

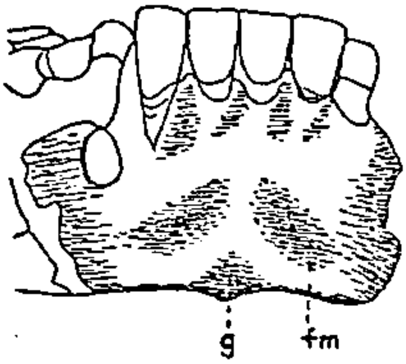


Figure 14. Mental trigonum of the *Sinanthropus* child B I (8-9 years old). Abbreviations:— g, gap between the original halves; fm, fossa mentalis.

The projection of the entire basal part of the front against the alveolar region characterizing recent man is a consequence of quite a different process which took place in the course of phylogenetic evolution. As stated above, this projection in part depends upon the existence of what H. Virchow (1920) termed "incurvatio mandibulæ anterior." The incurvatio is represented by a more or less deep furrow which courses from one side to the other just below the alveolar border. In this connection it is of no significance whether the foremost point of the alveolar border (incision) is perpendicular above the corresponding point of the basal part (gnathion) as in the case of the orthognathous jaw or whether it projects as in prognathism. The important factor marking the difference between apes and recent man remains the *presence* of that separating depression.

As I have demonstrated earlier (1934) the incurvatio itself is the result of two different effects, which nevertheless appear to be due to the same process. Compared with the mandible of the other primates the jaw of recent man is shorter and, instead of a more tapering front end, there is a flattened frontal plane. These differences are evident in particular in the shape of the dental arcade. The front teeth between the two canines are arranged in a straighter line in recent man, while in monkeys and apes they rather form a curve. This change is attributed to a real retraction of the frontal part of the alveolar region, in association with another process. All teeth of recent man which occupy the dental arcade previous to M_1 have undergone a gradual decrease in size, which became effective in crowns as well as in roots, but more especially in the latter. This decrease particularly prominent in the canine must influence the bulkiness and most of the thickness of the alveolar part within the entire area occupied by the roots. In contrast to the reduction of this part the basal region which offers the working field for muscle action and dynamic efficacy is much less affected. Thus, the lower part retains its position, so to speak, and consequently projects beyond the reduced upper part. In this way the mentum was formed.

It is evident that both processes, namely the formation of the mentum osseum and that of the trigonum mentale discussed above, though different in the special way of development, are connected with each other. The formation of a more flattened frontal part instead of the originally more pointed one is the other cause for the two processes, namely the reduction of the teeth and the alveolar part on one hand, and the formation of the basal gap within the symphyseal area and the trigonum mentale respectively on the other.

The existing conditions in the mandibles pertaining to *Sinanthropus* yield a reliable proof for the correctness of such an assumption. The comparison of the dental arcades of jaws G I and H I with that of the Heidelberg jaw and that of recent man (textfigs. 77-80, 84-88) demonstrates clearly the change in the outline of the arcade. However, this question will be discussed more in detail elsewhere. As to the incurvatio mandibulæ anterior there exists a slight depression which can best be seen in a profile view of jaw H I, indicating the beginning of a separation of the basal part from the alveolar process (Plate VII, fig. 1, Plate XI, fig. 2; textfig. 4). This incurvatio is much more marked in the jaws within the Neanderthal group, as for instance in the Krapina jaws H and I and in that of Spy I. Unfortunately, the Heidelberg jaw is damaged in this particular region, but it seems to me that there was present also a depression similar to that observed in *Sinanthropus* jaw H I.

As it is planned to discuss the teeth of *Sinanthropus* in a separate publication, it is sufficient here to remark that in spite of the great differences in size due to sex (Weidenreich, 1935) the crowns of the teeth as a whole are much larger than those in recent man. However, the decrease in size is still more apparent when comparing the length of the roots. In my often quoted publication (1934) I gave comparative views on what I termed the "root area." The latter designation involves the whole of the front region embraced by the roots of the incisors and those of the canines of the two sides.

An attempt was made by the writer in 1934 to illustrate the gradual reduction of the roots and the area occupied by them. In the female gorilla chosen as an example for the anthropoids with large canines and long roots the size, the depth and the direction of the alveoli was determined by removing the teeth and projecting their outlines on the anterior surface of the jaw as well as the outlines in profile view by means of Schwarz' stereograph (textfigs. 15 and 16). The median plane is also traced in profile view. The roots converge toward the midline and almost reach to the basal margin. The area embraced is represented by dotted lines. The roots of the lateral incisors are considerably shorter and more slender than those of the canines but nevertheless they occupy two thirds of the symphyseal height. They slightly converge to their tips too. The roots of the medial incisors are still shorter and more slender, standing upright and scarcely pass beyond the middle of the symphyseal height of the jaw. The profile view also shows how far the area extends downwards but at the same time it reveals to what extent the thickness of the front part of the jaw depends upon the space occupied by the roots

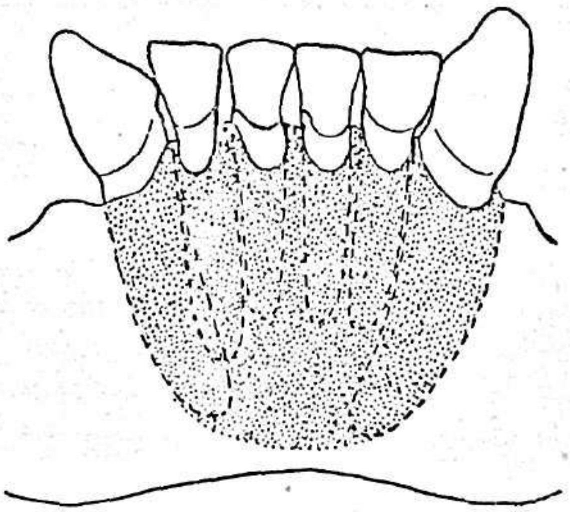


Figure 15. Frontal part of the mandible of a female adult gorilla. The dotted field represents the root area; the interrupted lines indicate the contours of the respective tooth roots traced in correct frontal projection. Natural size.

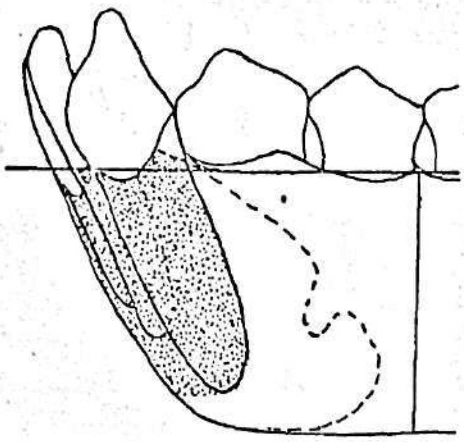


Figure 16. The same as in fig. 15 in profile view, the median section being indicated by interrupted lines. Natural size.

of these teeth. Thus, these two figures show at a glance that the inclination of the entire front part, the projection of the alveolar border and the gradual recession to the basal margin is very closely connected with the length and thickness of the roots of the front teeth, especially of the canines. The skiagram of the frontal part of an adult female orang (Plate VI, fig. 9) reveals the same conditions, especially in regard to the length of the canine roots.

In striking contrast to the feature described above are the conditions prevailing in recent man. Two characteristic types are given in textfigures 17, 18, 19 and 20; one of them represents an Australian native with an orthognathous mandible (textfigs. 17 and 18) and the other a Malayan with a pronounced prognathism of the jaw (textfigs. 19 and 20). The Australian jaw exhibits only a shallow incurvatio with relatively large teeth and long roots, while the Malayan jaw shows an extraordinary deep incurvatio with relatively large teeth and short roots. A comparison of the two respective types with the gorilla shows that in recent man a marked reduction of the tooth size, especially in length and thickness of the roots, took place. The area occupied by the roots is much smaller in every respect and the considerable shortening of the roots is also evident. However, these figures at the same time also reveal that (1) some relation exists between the depth of the incurvatio and the robustness of the roots and (2) that the prognathism restricted to the alveolar process like that in recent man (textfig. 20) has no connection with the formation of a prominent chin (mentum osseum), the latter depending entirely upon the existence of an incurvatio.

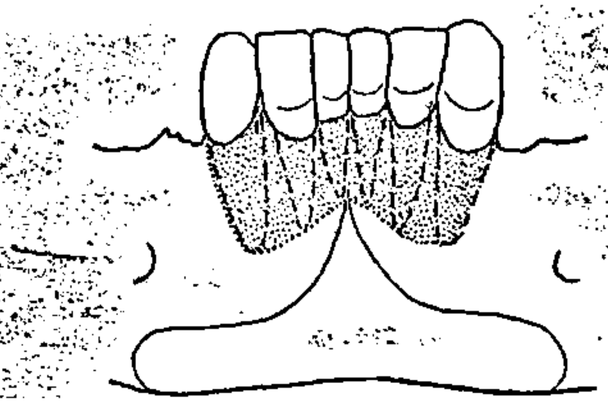


Figure 17. Frontal part of the mandible of a modern Australian native. The root area is illustrated in the same way as in fig. 15.

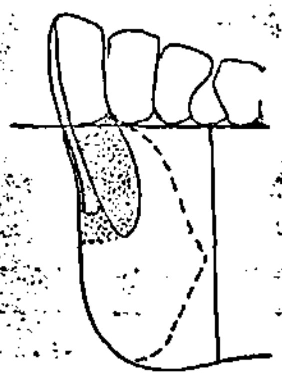


Figure 18. The same as in fig. 17 in profile view.

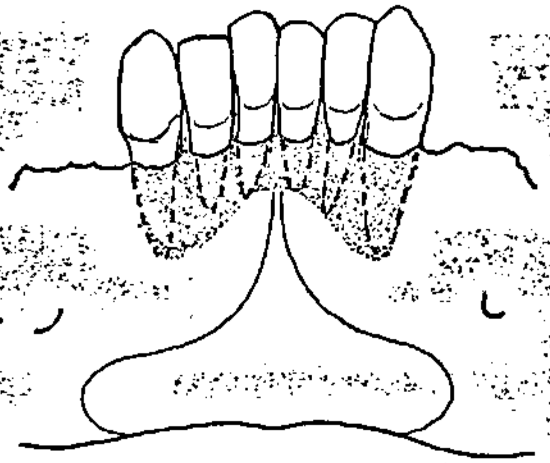


Figure 19. Frontal part of the mandible of a modern Malayan showing a strongly pronounced alveolar prognathism. Root area given in the same way as in fig. 15. Natural size.

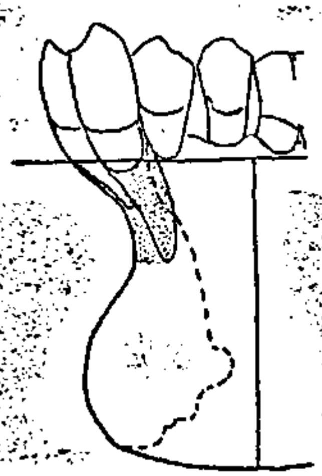


Figure 20. The same as in fig. 19 in profile view. Natural size.

It is of the greatest interest to compare the conditions existing in the Heidelberg jaw or in another representative of the Neanderthal group with the gorilla on the one hand, and with recent man on the other. With regard to the Heidelberg jaw the writer used skiagrams of front and profile views kindly supplied by Dr. Rüger, Tryfus and Weissenfels of Heidelberg. Textfigures 21 and 22 are accurate reproductions of the corresponding photographs. These skiagrams of the Heidelberg jaw show striking differences when compared with the jaws of recent man. They also reveal the fact that the reduction of the crown size did not keep pace with the reduction of the roots. Although in the Heidelberg jaw the size of the crowns of the front teeth does not exceed that of recent man, their roots, especially those of the canines, are much longer and thicker than in corresponding teeth of recent man. This fact was overlooked by van den Broek (1932) who concluded from the relative smallness of the teeth of the Heidelberg jaw in contrast to the extraordinary bulkiness of the mandible that the formation of the chin could not be the consequence of a phylogenetic reduction in tooth size. As to the Neanderthal group I wish to refer to the figures given for the mandible of La Naulette quoted in my publication of 1934 (fig. 69 I). In this case the area is smaller than that of the Heidelberg jaw but relatively much larger than that of recent man.

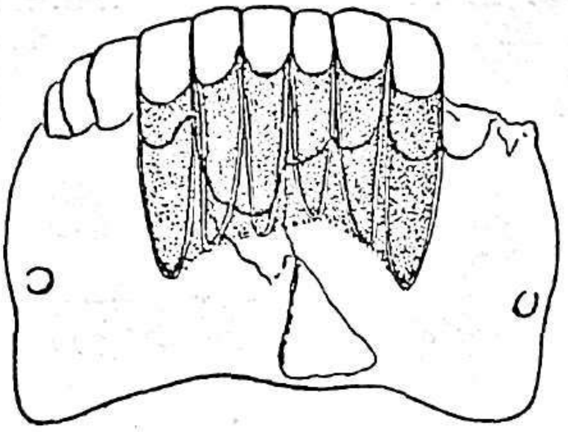


Figure 21. Frontal part of the Heidelberg mandible. Root area traced on the basis of photographs and skiagrams. Natural size.

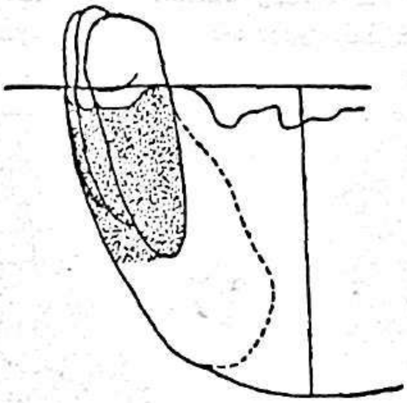


Figure 22. The same as in fig. 21 in profile view. Natural size.

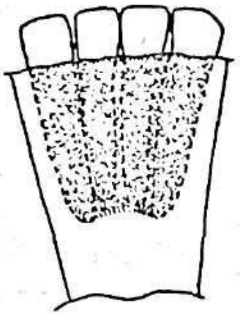


Figure 23. Root area of the mandible of *Sinanthropus* child B I (with permanent incisors) traced on the skiagram (Plate VI, fig. 5). Natural size.

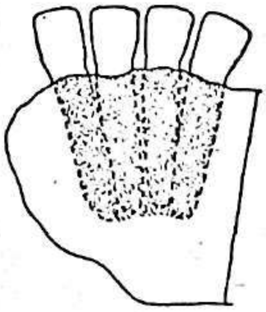


Figure 24. Root area of the mandible of *Sinanthropus* child B V (with permanent incisors) traced on the skiagram (Plate IX, fig. 3). Natural size.

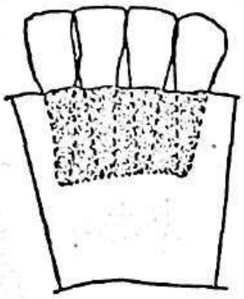


Figure 25. Root area of the mandible of a modern North Chinese child of the same age as *Sinanthropus* B I (with permanent incisors) traced on the skiagram (Plate VI, fig. 6). Natural size.

Sinanthropus furnishes us with a good example for the demonstration of the relation between the size of the teeth and their roots, the thickness of the alveolar part and the formation of the incurvatio respectively. In both juvenile jaws, namely B I and B V the permanent incisors are fully developed so that the length of their roots and the space they occupy within the area can be ascertained and compared with a recent child of the same stage of dentition. The skiagram of the frontal part of *Sinanthropus* jaw B I (Plate VI, fig. 5) and that of jaw B V (Plate IX, fig. 3) demonstrate clearly the length of the roots in question. The skiagrams of the corresponding parts of modern Chinese children of the same stage of dentition (Plate VI, figs. 6 and 7) permit us to compare the conditions in both cases. Textfigures 23, 24 and 25 show the differences illustrated by the method of marking the root area. As the skiagram (Plate XII, fig. 4) reveals, on the left side of *Sinanthropus* G I which belongs to an adult male individual only the root of the canine is totally preserved, those of the two incisors being partly broken off. But since the actual length of the roots of the two latter teeth can be measured on the basis of the preserved roots in B I and B V, it is possible to reconstruct also the area of the roots of jaw G I. For this purpose the skiagrams in frontal and profile views were made use of after having adjusted the jaw in the correct orientation to the alveolar plane. Textfigures 26 and 27 represent skiagrams completed by drawing. For *Sinanthropus* jaw H I which belongs to an adult female in which the front teeth are not preserved skiagrams were made of the preserved alveoli (Textfig. 28).

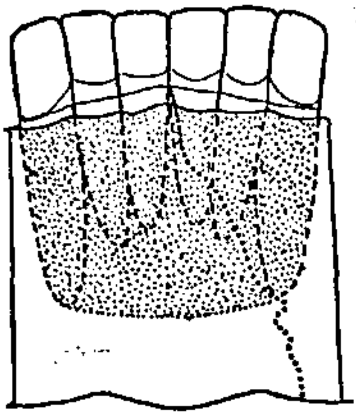


Figure 26. Root area of the mandible of the adult *Sinanthropus* male G I traced on the basis of a skiagram of which the right side has been restored according to the preserved left side (Plate XII, fig. 4), the length of the incisor roots having been substituted to correspond to the root length in figs. 24 and 25. Natural size.

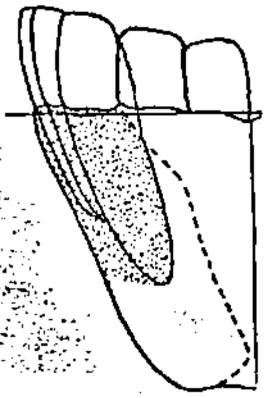


Figure 27. The same as in fig. 26 in profile view.

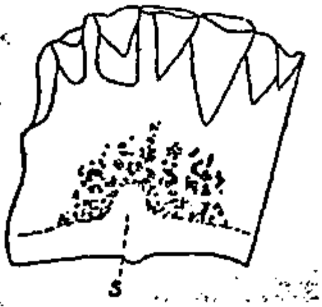


Figure 28. Drawing of the skiagram of the frontal part of *Sinanthropus* mandible H I viewed from the lingual side. Note the shaded area in the chin region(s). Natural size.

The appearance of the root area of the male *Sinanthropus* jaw G I shows that the roots in question are much longer than those of recent man and slightly also exceed in length those of the Heidelberg jaw. *Sinanthropus* H I remains behind in this respect, which is apparently due to the fact that the canines of female individuals corresponding to the difference in size of the jaws are smaller in all their dimensions (compare Weidenreich, 1935, Plate II, fig. 3) than those of males.

An approximate computation of the height of the area in relation to the height of the whole jaw and of the single tooth, beginning with the medial incisor to the canine, yields the following figures:

Gorilla ♂	55-89%
Sinanthropus G I ♂	47-69%
Heidelberg ?	39-58%
Australian ♂	33-50%
Malayan ♂	19-42%

In the juvenile jaws the extent of the area is computable for the incisors only, since the canines are deciduous teeth.

Sinanthropus B I ♀	62-69%
Sinanthropus B V ♂	53-67%
Modern Chinese child	43-44%

A great difference exists between the adult and juvenile stages because in the latter the length of the roots in relation to the height of the jaw is much greater than in the adult mandible. This feature is due to the fact that the incisors achieve their definite length before the jaw attains its definite height.

As to the difference between male and female it may be that the reduction in the tooth size occurring in the course of human evolution advances faster in the latter than in the former. Perhaps it is a consequence of this that the relief of the front part in *Sinanthropus* jaw H I is more developed in the sense of the definitive stage than seems to be the case in *Sinanthropus* jaw G I the middle part of which is missing.

Therefore all observations on the *Sinanthropus* jaws foster the assumption that the prominence of the mentum osseum is the result of the reduction of the front teeth, especially of the canines, which causes a decrease in size of the entire alveolar process and again as a consequence of this a protruding of the basal part beyond the alveolar part.

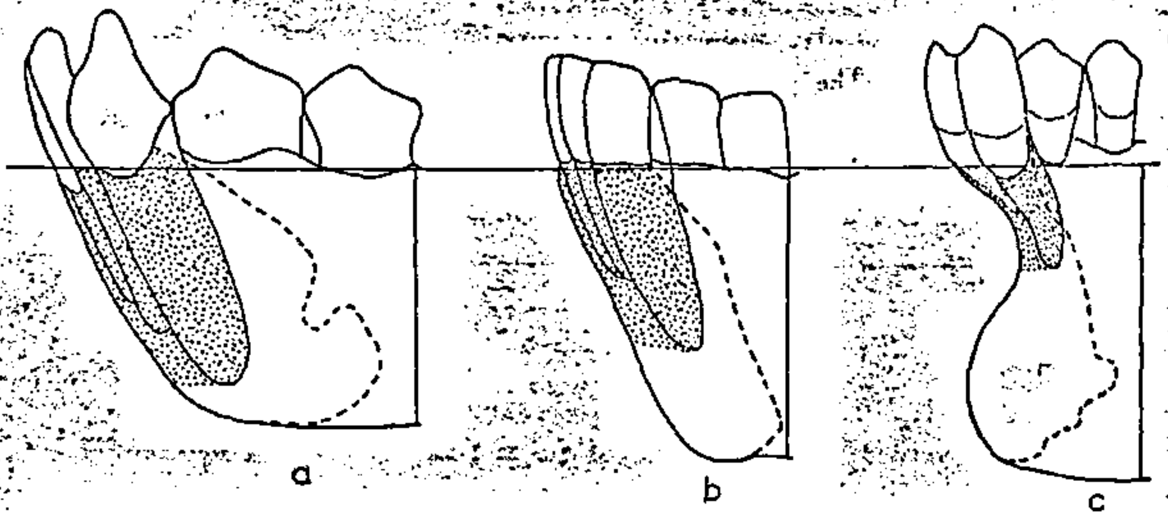


Figure 29. Comparative profile views of the root areas of female gorilla (a); *Sinanthropus* G I (b) and a modern Malayan (c). All three views are oriented in the alveolar plane. The drawings illustrate at the same time the anterior alveolar arch (p. 108 & ff). Natural size.

9 Textfigures 20 a-c demonstrate clearly that this reduction takes place especially at the roots and that the formation of the "incurvatio" depends directly upon the extent of this reduction. For this purpose I placed side by side profile and median projections of the gorilla jaw (textfig. 16), that of *Sinanthropus* jaw G I (textfig. 27) and that of the jaw of recent Malayan (textfig. 20) which exhibits a very pronounced alveolar prognathism combined with large and high crowns but short and small roots of the front teeth.

A comparison of the *Sinanthropus* jaws with those of the Neanderthal group with reference to the chin (mentum osseum and trigonum mentale) shows that *Sinanthropus* approaches closely the Krapina mandibles E and H. The adult jaw of Ehringsdorf may also belong to the same type. I even believe that the differentiation of the mental trigonum in *Sinanthropus* may be slightly more advanced than in the case of the Krapina jaws. Yet the Heidelberg jaw appears to be more primitive in this respect. However, one fact should not be overlooked. Both *Sinanthropus* jaws in which the region in question is well preserved, namely the juvenile jaw B I and the adult H I, very probably belong to female individuals judging by the size and bulkiness of bone and teeth. Male individuals in which the chin region is completely preserved have as yet not been recovered. The robustness and the absence of a well developed relief in the male jaw G I lead to the supposition that the details of the chin region are not as fully developed as in the case of the female jaw H I. Therefore, it is possible that a male jaw of *Sinanthropus* with the particular region preserved may resemble more closely the jaw of Heidelberg in this respect than those we now have at our disposal.

3. The inner surface of the frontal part — planum alveolare, tori transversi, fossa genioglossi, spinæ mentales.

The inner surface of the frontal part of the human mandible has repeatedly been the object of extensive investigations based upon the comparative method of examination. With reference to this the reader is referred to the publications by Gorjanovic-Kramberger (1909), Toldt (1915), Thomson (1916), Holl (1919), H. Virchow (1920) and those by the writer (Weidenreich, 1934) in which the questions concerned were discussed in detail.

The mandible of gorilla furnishes the best example for an extensive study of the details under consideration. The inner surface, the appearance of which may be simplified by the outline of a median section (textfig. 30, a), runs from the alveolar border on an inclined plane (p) down and backwards. This plane is known under different names, the English called it "epimedial torus", Walkhoff "Lingualwulst", Schwalbe "planum alveolare", Virchow "promontorium." In its upper part the planum is more or less concave and proceeds gradually to a strong swelling (ts). Below this swelling there is a relatively large cavity (fg) extending frontwards and sidewards, *forming a kind of niche. The bottom of this niche is represented by another projection directed straight* backwards. The posterior margin of this projection at the same time is the lower margin (ti) of the jaw. All the formations quoted have specific names. The upper swelling corresponds to Holl's torus transversus superior, the niche to Toldt's fossa genioglossi and the lower projection to Holl's torus transversus inferior and Virchow's basal plate ("Basalplatte"). It deserves special mention that the torus transversus superior continues lateralwards in the elevations of the posterior alveolar process projecting inward beyond the basal part. The torus and the swelling combined form what Virchow (1920) called an "arcus intermedius", or perhaps better: inner mandibular arch. With this arch we deal with the narrowest inner contour of the mandible.

The alveolar planum itself does not offer any particularity worth mentioning. As the name indicates, the fossa genioglossi was considered the site where the genioglossi take their origin. But H. Virchow pointed out that this interpretation is not correct, for those muscles do not attach to the depth of the niche itself but to the upper side of the torus inferior. At this site the muscular area of the genioglossi and geniohyoidei can be recognized. In juvenile gorillas they consist of two pairs of small areas, a superior larger one and an inferior smaller one; the first pair separated by a narrow low ridge gives origin to the genioglossi. The inferior areas adjoin closely the superior, being separated only by a narrow transversal ridge from the latter. In the adult gorilla the basal plate developing backwards takes a more horizontal direction, with the areas of the genioglossi also extending backwards; those of the geniohyoidei shift to the outermost margin of the plate and even beyond this by means of a secondary spine which is formed in the midline between the two muscles touching each other. In the fore-wall of the niche there are small foramina, the numbers of which vary, through which vessels enter the bone.

In the adult chimpanzee (textfig. 30 c) the relief of the inner surface is as a whole the same as that in gorilla, with the exception that the geniohyoid spine is not developed generally. However, in orang (textfig. 30 b) the appearance is different in so far that the real alveolar planum is more or less absent and the inner surface follows a line parallel to the outer contour. Corresponding to this the torus superior is less pronounced and the fossa genioglossi generally forms a larger and shallower depression.

In contrast to the anthropoids the inner surface of man offers a very different aspect (textfig. 30, d and e). An alveolar plane is missing; only in jaws with strongly pronounced alveolar prognathism the slope of the inner surface is not so abrupt as in the case of orthognathous jaws (d) and declines in its upper part moderately backwards and downwards (e). In this case also the torus superior is indicated as a slight swelling (e) beyond which the basal part of the mandible again courses forward. However, it must be noted that an indication of planum and torus sometimes also occurs in orthognathous jaws. A fossa genioglossi does not exist as a rule, but it may be found occasionally as stated by Toldt (1915), Thomson (1916) and by the writer (1934). In such cases the fossa is represented by a small hollow impression. The most conspicuous difference between recent man

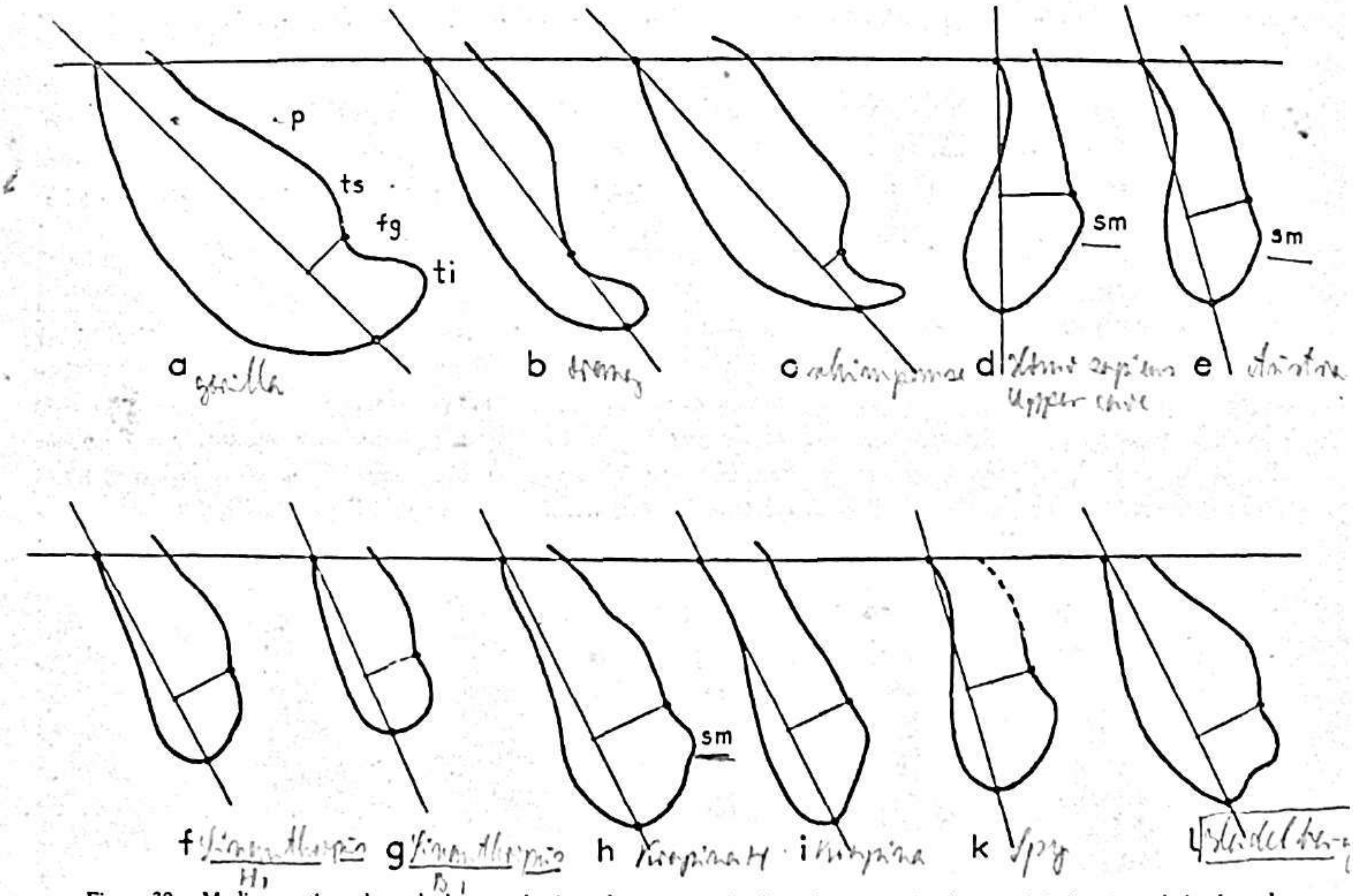


Figure 30. Median sections through the symphysis to demonstrate (1) their shape; (2) the degree of inclination of the frontal part to the alveolar plane and (3) the position of the foramen supraspinosum in relation to the height of the symphsis. Designations:— a, adult female gorilla; b, adult female orang; c, adult male chimpanzee; d, Palæolithic recent man of Choukoutien (No. 101); e, modern Australian native (No. 24); f, adult female *Sinanthropus* H I; g, *Sinanthropus* child B I; h, Krapina H; i, Krapina I; k, Spy I; I, Heidelberg mandible. Abbreviations:— fg, fossa genioglossi; p, planum alveolare; sm, spina mentalis: ti, torus transversus inferior; ts, torus transversus superior. Natural size.

and anthropoids exists in the basal part of the inner surface which is occupied by the mental spines. The spines are not located at a special swelling like the torus inferior but project from a more even plane. The spines consist, if well developed, of two pairs of small crests, an upper and a lower pair. The upper pair is large and its eminences divert further from each other, while the lower pair is smaller, the eminences almost touching each other.

Besides these peculiarities there is a great difference in the position of the basal part in relation to the frontal plane. A comparison of textfigure 30 *a* with textfigure 30 *d* shows that in recent man the outline of the inner surface runs forward below the spines for the attachment of the genioglossi (sm). In this way the spines present that part which projects backwards furthest. Yet in gorilla the lower spines (ti) act in the same way. Thus the impression arises that the basal part of man seems to have turned forward to the same extent as the alveolar part receded backwards. Although as great as the variability of the whole region in question may be, yet the general character remains the same. Textfigure 30 reveals still another peculiarity of man when compared with the anthropoids. In most cases of recent man a single foramen opens into the bone immediately above the upper pair of the mental spines, corresponding to the foramina of the fossa genioglossi in anthropoids mentioned above. This foramen marks a characteristic boundary. The part of the jaw situated above this opening represents the alveolar part, the part below it the basal part. Textfigure 30, in which the position of this opening is indicated by a point, exhibits very clearly that in gorilla and chimpanzee the alveolar part is much higher and thicker when compared with the corresponding part in recent man, and that about the reverse holds good for the basal part. This change furthermore supports the assumption that the basal part, that is to say, the chin, projects as a result of a real reduction of the alveolar part.

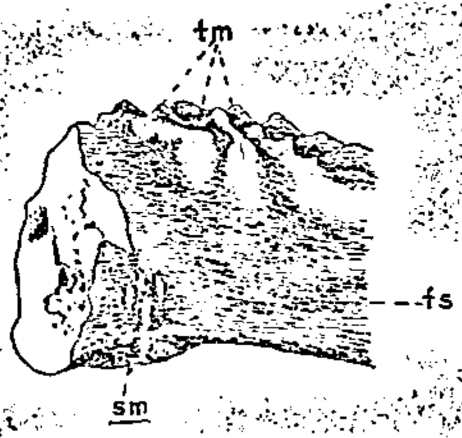


Figure 31. Lingual surface of the adult female *Sinanthropus* mandible H I, Abbreviations:— fs, fossa subalveolaris; sm, spina mentalis; tm, torus mandibularis. Natural size.

How is *Sinanthropus* in regard to all these peculiarities? The region in question is completely preserved in the adult jaw H I and in the juvenile jaw B I. In the adult jaw H IV the margin of the basal part is missing, but the region of the mental spines is preserved. In jaw H I the inner surface (Plate VII, figs. 2-4, Plate VIII, fig. 2; textfigs. 30 f and 31) is slightly hollow immediately below the alveolar border and rises to a flat, smooth and diffuse swelling which corresponds within this position to the torus superior. Below this the muscular area is developed very distinctly. It is about 9.5 mm long and about 7.5 mm broad and consists of a faint rough eminence which contrasts to the surrounding smooth surface. At this point there arise three spine-like formations, two superior ones forming a pair and one single inferior one (Plate VII, figs. 2-4; Plate VIII, fig. 2). The measurements of the superior spines are as follows:—

	left spine	right spine
length	3.4 mm	4.4 mm
thickness at the base	1.9 mm	1.5 mm
height of the medial border	1.0 mm	1.2 mm

The distance between the two spines is 3.5 mm. The single lower spine situated in the middle line and partly inserted between the two upper ones is narrower and longer than the latter:

length	6.2 mm
thickness at the base	1.2 mm
height	0.8 mm

Below the lower spine there is a fine grain-like eminence and directly below it a distinct spine belonging to the basal trigonum (see above).

The change in the course of the line occurs in the region between the upper and lower spines so that the latter are directed downward and backward. In the middle between and partly above the upper spines there are two foramina supraspinosa, a smaller and a larger one.

Jaw H IV (Plate IX, fig. 10 and textfig. 32) shows the same particularities as jaw H I. Just below the alveolar border a shallow depression is recognizable but an alveolar planum is not developed nor a real torus superior, although a corresponding swelling is faintly palpable. Beyond this a small and shallow depression is found which is followed by the muscular area. The area like that in jaw H I is situated at an indistinct elevation and consists of two long and narrow spines, one on each side. The spines slightly converge toward each other. Below the spines the jaw is broken off. The measurements of the spines are as follows:—

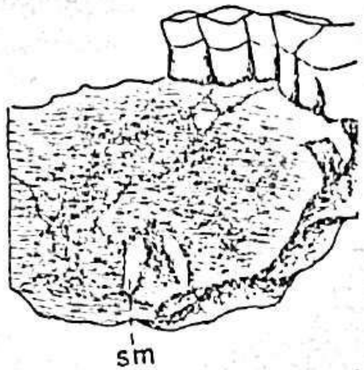


Figure 32. Lingual surface of the female adult *Sinanthropus* mandible H IV. Abbreviation:— sm, spina mentalis. Natural size.

	left	right
length	7.0 mm	8.0 mm
greatest breadth	2.2 mm	2.3 mm
height	0.4 mm	0.6 mm

The distance of the upper ends of the two spines amounts to 3.7 mm. A foramen supraspinosm cannot be found.

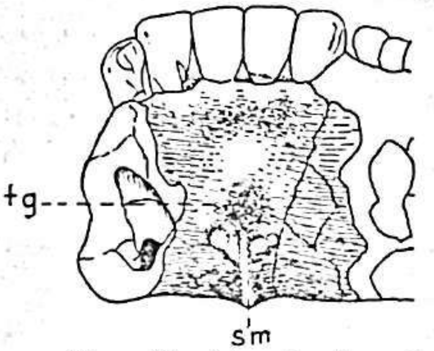


Figure 33. Lingual surface of the female *Sinanthropus* child B I. Abbreviations.— fg, fossa genioglossi; sm; spina mentalis. Natural size.

The juvenile *Sinanthropus* jaw B I has a different appearance (Plate II, figs. 5 and 7, textfigs. 30 g and 33). The alveolar border projects slightly. Below this swelling there is a distinct oval pit about 6 mm long in sagittal diameter. Next to this depression a well developed eminence is evident. It corresponds to the torus superior, even though it appears more like a blunt median tuber. The lower slope of this protuberance proceeds to a niche-like roundish pit at the bottom of which two small foramina superspinosa of unequal size are recognizable. Beyond this depression the surface rises again to form another eminence the lower margin of which represents the basal border of the jaw. This eminence corresponds to the torus inferior. At the site of this swelling there are three rough and elevated areas, two upper ones, one on each side and a narrow lower one just in the middle line. The upper areas extend with their upper ends into the niche and are separated from each other by a narrow smooth line which continues downwards to the median stripe-like area. The latter bends to the lower margin of the jaw.

The measurements of the three areas are as follows:

Upper areas, length: left, 4.5 mm; right, 3.5 mm; breadth: 8.2 mm (the two together).
Lower area, length: 6 mm; greatest breadth: 1.9 mm.

The upper part of the juvenile jaw B V (Plate IX, figs. 2, 4, 5) resembles more the adult jaw H IV than that of B I. The impression below the alveolar border, the torus superior and a slight depression beyond it are recognizable. The muscular area is partly damaged and partly broken off.

The juvenile jaw B IV (Plate VIII, fig. 7), the youngest of all the *Sinanthropus* jaws, is broken just in the middle but the fracture deviates laterally in the lower part so that the greatest part of the regions in question is missing. Nevertheless, it seems that a torus superior existed and is continued into a depression below it.

It is evident from this description that in regard to the details of the inner surface there is no fundamental difference between *Sinanthropus* and recent man. It may even be true in some cases that the torus superior and the fossa genioglossi are more pronounced in recent man than in *Sinanthropus*. Rather surprising is the aspect of the muscular area. Exactly in the same way as it is in recent man, there are mental spines resting on a moderately elevated base. It is true that the spines themselves are small but the same conditions may be found in recent man also. On the other hand the spines are very distinct and clearly developed. These conditions in the adult jaw are confirmed by those observable in the juvenile jaw. The latter jaw has more the appearance characterizing anthropoids, although the details are not so strongly pronounced as in anthropoids. In most cases of recent man of corresponding age the spines are only indicated by small rough spots which do not project beyond the general level of this region. It seems therefore that in the juvenile *Sinanthropus* jaw the pithecoid character is more realized and that it is lost in the course of individual growth until the definitive dentition is attained.

The close approach to recent man in this regard is all the more remarkable as the greater part of the mandibles of the Neanderthal group is more primitive and more anthropoid-like than those of *Sinanthropus*. The planum alveolare, the torus superior and the fossa genioglossi are especially marked in the adult jaw of Ehringsdorf and in the Heidelberg jaw (textfig. 30 l). The first mentioned would represent a very primitive type, provided that the exaggerated formation of the details in question is not the consequence of the doubtless pathological conditions of the alveolar part. The various Krapina jaws approach closely those of *Sinanthropus*, although the muscular area of none of them is so like that in recent man as it is in the case of *Sinanthropus*. In the Krapina jaws D, G and E mental spines are absent, their whole appearance resembling that of the juvenile *Sinanthropus* jaw B I. The same is true for the jaw of Spy I and that of La Naulette. In the Krapina jaws H and I (textfig. 30 h, i) mental spines are developed but according to the casts they only form an indistinct rough bony mass and do not show any clear differentiation such as found in the adult *Sinanthropus* mandibles.

I shall return to the statements just discussed in the following pages.

4. The inner surface of the lateral part: prominentia alveolaris, fossæ subalveolares, linea mylohyoidea — torus mandibularis.

The relief of the inner surface of the body in recent man is characterized by the position of the alveolar process in relation to the basal part of the body. Both parts of the body, namely the alveolar process as well as the basal border form arches, but the posterior part of the first is narrower than that of the second. The alveolar process therefore projects here medianwards and hangs over the basal part (textfig. 34). The overhanging process appears as a console-like prominence which may be called "prominentia alveolaris" (pa). The prominence begins approximately in line with the first premolar, corresponding to the increasing narrowness of the body, and gradually becomes stronger so that it obtains its largest development in line with the last molar. Below the prominence the surface recedes laterally to form a more or less shallow depression which sometimes assumes the appearance of a furrow. A part of this formation corresponds to the so-called fossa submaxillaris (fs). The location of the prominence in relation to the fossa and the lower margin can best be demonstrated by a cross section through the body behind the second molar. Textfigure 34 illustrates such sections perpendicular to the alveolar plane, h-k pertaining to recent man.

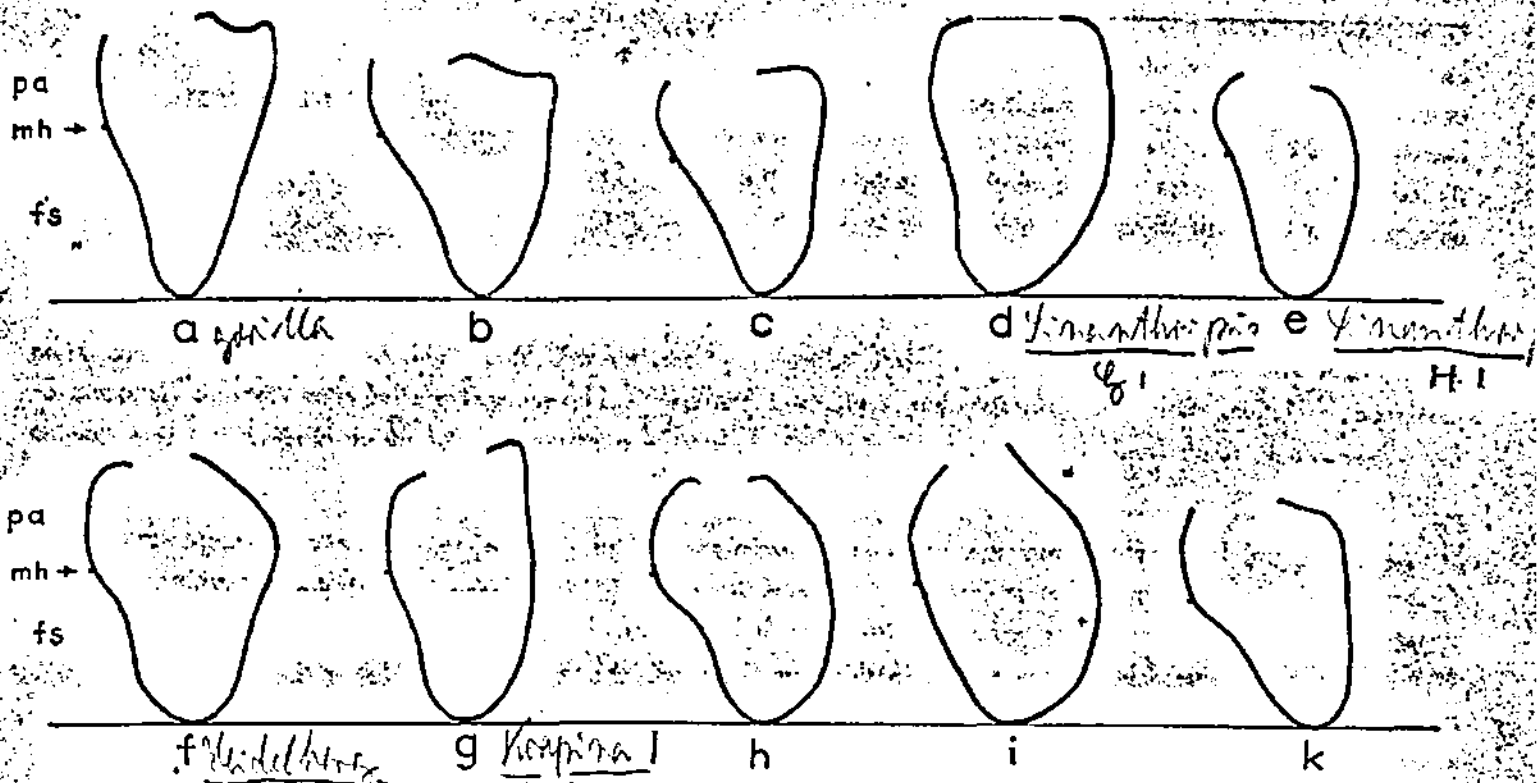


Figura 34. Cross sections through the left side of the body of the mandible between M_2 and M_3 perpendicular to the alveolar plane. The arrow pointing to the lingual side indicates the position of the linea mylohyoidea. Designations:— a, adult female gorilla; b, adult female orang; c, adult male chimpanzee; d, adult male *Sinanthropus* G I; e, adult female *Sinanthropus* H I; f, Heidelberg mandible; g, Krapina I; h, modern Australian native (No. 14); i, recent Prehistoric Chinese (Kansu 404/15); k, modern North Chinese male (No. 17). Abbreviations;— fs, fossa subalveolaris; mh, linea mylohyoidea; pa, processus alveolaris. Natural size.

The prominence itself is divided into two parts, an upper and a lower one. The surface of the upper prominence is more or less elevated and rough, while the lower one is absolutely smooth. The first terminates in an irregular line which at times is well developed and then again only faintly indicated (textfig. 35, mh). This line seems to form the boundary between the two areas and represents the attachment for the mylohyoid muscle. It is therefore called "linea mylohyoidea." In textfigure 34 its position is marked by a point (mh). The line does not at all determine the lower end of the prominence as described by some authors. H. Virchow (1920) for instance described the linea mylohyoidea as a brim caused by abrupt thinning of the bone which is thicker above this line. It only terminates the elevated and rough part of that swelling. The unevenness is at times and in special places very pronounced and represents characteristic tubercles (textfig. 35) which then represent the so-called torus mandibularis to be discussed separately.

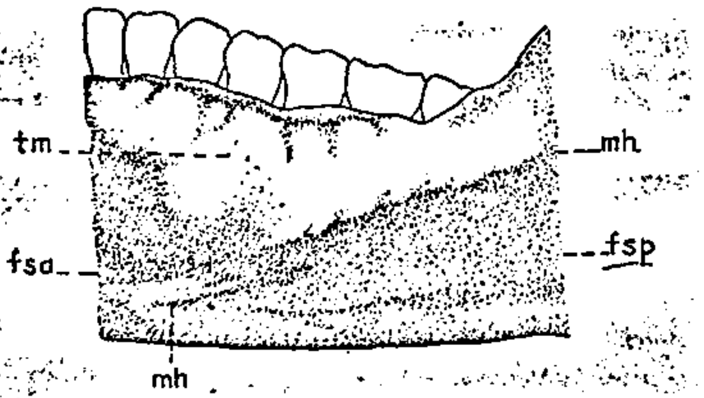


Figure 35. Torus mandibularis of modern North Chinese man (No. 17). Abbreviations:— fsa, fossa subalveolaris anterior (fossa sublingualis); fsp, fossa subalveolaris posterior (fossa submaxillaris); mh, linea mylohyoidea; tm, torus mandibularis. Natural size.

The fossa submaxillaris is occasionally more marked by a slight projection of the lower margin toward the inner side of the jaw. The posterior end of the prominence continues behind the last molar with a thickening which descends from the coronoid process of the ramus. Lenhossek (1920) called this eminence "torus mandibulæ", an expression which may cause some confusion because much earlier the term "torus mandibularis" was associated with a very different formation. I therefore propose the term "torus triangularis" for Lenhossek's protuberance; the explanation will be given below. Corresponding to this direct connection between body and ramus the fossa submaxillaris in many cases proceeds directly to the depression between the torus triangularis and the tuberositas pterygoidea starting from the mandibular foramen. The roughness of the alveolar prominence ceases upon reaching the torus triangularis and the same is true for the mylohyoid line. At times the alveolar border lateral to M_3 is represented by a sharp edge with tubercle-like elevations.

H. Virchow (1920) pointed out that the fossa submaxillaris and also the fossa sublingualis (see below) have nothing in common with the glands after which they are termed, these glands being only in very loose topographic relations with the corresponding regions of the jaw. The same author believes that the formation of those fossæ would result from the decrease of thickness during the transformation of the anthropoid jaw into that of a man.

As to the fossa sublingualis the extent and deepness of this pit is very variable in recent man. It is located laterally from the mental spines and in the same transverse level as these. Backwards it continues with the fossa submaxillaris but is usually separated from the latter by a faint swelling over which the mylohyoid line courses in the direction from above and backwards to the front and downwards (textfig. 35, fsa). This line thus marks the boundary between the two fossæ. Toward the alveolar part the fossa sublingualis is limited by a broad swelling which corresponds to the torus superior and its lateral continuation or in other words the fossa is situated just below the anterior parts of the inner mandibular arch (compare above). The fossæ sublinguales of both sides are not infrequently connected in the symphyseal part of the jaw by a transverse depression identical with that described above and one which partly corresponds to the fossa genioglossi.

The writer agrees with H. Virchow's finding that the existence of the two fossæ, fossa submaxillaris and fossa sublingualis, is independent from the glands in question and that the relations between them are purely topographic in nature and rather subordinate. As mentioned above the fossa submaxillaris results from the incongruity between the width of the alveolar arcade and that of the basal arcade. The fossa sublingualis owes its formation to the same conditions, representing only the anterior part of the fossa submaxillaris from which it is separated merely by the attachment for the mylohyoideus (textfig. 35). It would therefore be correct to change the terms of these formations and to call the whole depressed part of the inner surface "fossæ subalveolares." The fossa submaxillaris should be termed "fossa subalveolaris posterior" and the fossa sublingualis "fossa subalveolaris anterior."

I regret to have to oppose H. Virchow in his assertion that the pits in question do not occur in anthropoids, with the exception of the fossa sublingualis which is found in the orang. Corresponding to its real significance the fossa subalveolaris is common in all catarrhines with a greater or lesser degree of development, and the same is true for the fossa sublingualis. In anthropoids where the body of the jaw is generally very robust and thick, the alveolar prominence slopes equally to the lower margin. Nevertheless, not infrequently a more or less pronounced curvature below the prominence can be observed here, conforming entirely to the fossa subalveolaris in recent man (textfig. 34, compare *a-b* with *h-k*). It must be admitted that generally this curvature is not as deep as in the case of recent man but on the other hand it should be taken into consideration that the variability is very great. In strong jaws, for instance in the specimen the outer surface of which was reproduced as textfigure 2, the fossa is not more developed than in the case of the gorilla illustrated in textfigure 34 a. As the fossa sublingualis represents only the anterior part of the fossa subalveolaris the same conditions hold good for this formation.

The same inaccuracy is met with in reference to the statement on the occurrence of the mylohyoid line in anthropoids. Lenhossek (1920) states that it is completely absent in the latter. As mentioned above, H. Virchow tries to explain its alleged absence by the statement that the thickness of the bone in this place does not diminish so suddenly in apes as is true for recent man.

In contrast to the above finding I observed the linea mylohyoidea in all three anthropoids, even though its appearance varied. In the case of an adult male gorilla the linea is represented by a jagged line which has its beginning in the region of the "torus triangularis" (textfig. 59 mh) and runs obliquely forward and downward and terminates at the torus transversus inferior near the middle line. With its posterior half the line delimits the rough area of the alveolar prominence which also exists in anthropoids. The anterior half is not so distinct but is, in any case, clearer than in recent man. In the case of an adult male orang of our collection the linea is formed in the same way and to the same extent (textfig. 60 mh). The linea is also recognizable in an adult male chimpanzee as a fine boundary line delimiting the rough area of the alveolar prominence (textfig. 61 mh). It may be admitted that the line in question is not so strongly developed in anthropoids as is generally the case in recent man. However, there remains no doubt that it really exists and therefore there is no fundamental difference in its appearance in man and apes.

In *Sinanthropus*, especially in the well preserved H I (Plate VII, figs. 2, 4; Plate VIII, fig. 2 and textfigs. 36 and 37) the posterior part of the alveolar prominence projects far inwards, the fossa subalveolaris therefore being very prominent (fsp). The connection between the prominence and the torus triangularis (ttr) is remarkably

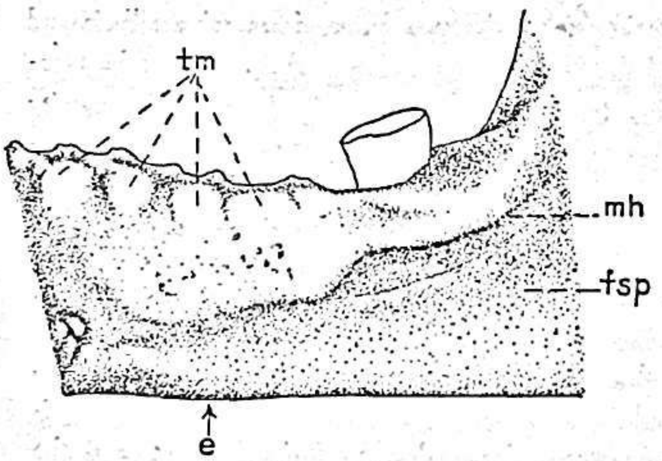


Figure 36. Lingual surface of the mandible of the female *Sinanthropus* H I. Abbreviations:— e, elevation near the lower margin; fsp, fossa subalveolaris; tm, torus mandibularis; mh, linea mylohyoidea. Natural size.

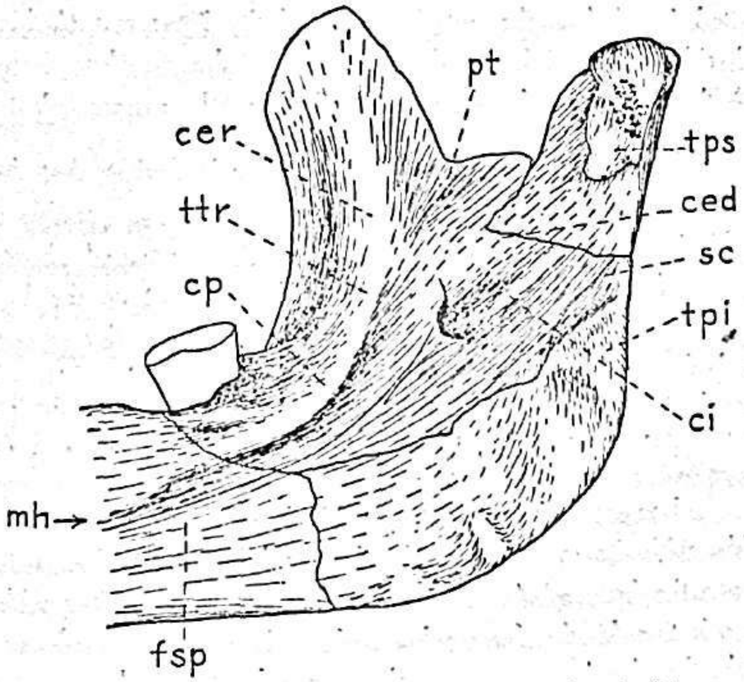


Figure 37. Medial surface of the ramus of the female *Sinanthropus* H I. Abbreviations:— ced, crista endocondyloidea; cer, crista endocoronoidea; ci, crista intermedia; cp, crista pharyngea; fsp, fossa subalveolaris; mh, linea mylohyoidea; pt, planum triangulare; sc, sulcus colli; tpi, tuberculum pterygoideum inferius; tps, tuberculum pterygoideum superius; ttr, torus triangularis. Natural size.

close as the interior edge of the latter continues directly to the posterior end of the prominence. The rough area of the prominence in the region of M_3 appears to rest on it as a special formation separated from the lower smooth party by a threshold-like undulating line — the linea mylchyoidea (mh). Towards the anterior end of the rough area the line diverges from it and proceeds as a very fine stripe to the lower end of the mental spines. A fossa sublingualis in the form of a separated anterior part of the fossa subalveolaris beyond this line does not exist. The fossa subalveolaris (fsp) itself is limited at its lower boundary by an appreciable elevation which strengthens the inner surface of the lower margin of the jaw (e).

In jaw G I (Plate IV, figs. 2 and 4) no such abrupt slope of the posterior part of the prominence toward the fossa subalveolaris exists as is present in H I (textfig. 34 *d*), because the swelling of the prominence flattens gradually. Therefore a fossa alveolaris is only faintly developed. Unfortunately, the anterior parts of this region are damaged but nevertheless it can be seen that here also the lower margin is elevated inwards. The linea mylohyoidea represents the lower limit of the rough area of the prominence which, however, cannot be traced beyond the level of M_3 on account of its damaged condition.

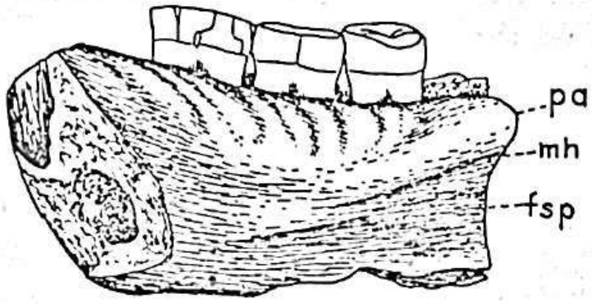


Figure 38. Lingual surface of the body of the female *Sinanthropus* mandible A II. Abbreviations:—fsp, fossa subalveolaris; pa, prominentia alveolaris; mh, linea mylohyoidea. Natural size.

Sinanthropus jaw A II occupies a position intermediate between the two preceding jaws (Plate I, figs. 2,4,6; text-fig. 38). The prominentia alveolaris is well developed and projects considerably inward but the transition to the fossa subalveolaris, which is also very distinct, occurs gradually. The linea mylohyoidea which bounds the rough aera is edge-like in its posterior part. It can be traced to almost the lower margin, then it disappears. A distinct "fossa sublingualis" does not exist.

Jaw H IV (Plate XI, fig. 12) is so badly damaged that only the lower part of a strongly projecting prominence and its well developed fossa subalveolaris is observable.

The juvenile jaw B I (Plate II, figs. 2, 4) exhibits the alveolar prominence, the fossa subalveolaris and the thickening of the lower margin to be exactly the same as in jaw H I and the same is true for the linea mylohyoidea. A fossa sublingualis is not evident. The other juvenile jaws show approximately the same features as far as they are preserved in the region in question.

With reference to the prominence, the fossa and the linea mylohyoidea the Heidelberg jaw resembles *Sinanthropus* jaw H I more than jaw G I. A fossa sublingualis does not exist unless the lateral part of the wide fossa genioglossi is not considered as including a depression corresponding to that fossa. The adult Ehringsdorf jaw forms an exception in this respect. It is not so much the strong inward projection of the whole processus alveolaris as the deepening of the underlying parts that produces an extremely furrow-like fossa subalveolaris, the two parts of which (posterior and anterior) are likewise very strongly outlined. In the juvenile jaw of Ehringsdorf these details are less developed. Among the other jaws of the Neanderthal group the mandible I of Krapina approaches *Sinanthropus* jaw H I most closely. In comparison with this the latter appears to be a duplication or a very insignificant variation.

There is a distinct difference in the appearance of the inner surface under discussion between *Sinanthropus* jaw G I and the jaws H I, H IV and A II. However, this difference is not at all greater or more substantial than what is true in jaws of recent man or in those within the Neanderthal group. Viewed from the phylogenetic standpoint essential differences cannot be recognized to be evident between *Sinanthropus*, Neanderthal and recent man. The variations observed with respect to details are all of the same nature in the three hominid types. It seems that they may depend on the individual robustness and size of the jaws rather than on the place occupied within the order of human evolution. A comparison of the various cross sections in textfigure 34 makes this evident. The contours of the jaws of gorilla (a), *Sinanthropus* G I (d), Krapina I (g) and Prehistoric Chinese (i) do not reveal any remarkable distinction with regard to the relief of the inner and outer surfaces. Only the place, where the linea obliqua descending from the ramus meets the body, is marked by a sharp angle in anthropoids (textfig. 34 a-c, right upper corner) while the corresponding region in hominids is rounded off, the reason being that the linea runs further forward in anthropoids than in hominids. The only differences of some comparative value refer to the low level at which the mylohyoid line terminates and the absence of a "fossa sublingualis." Davidson Black (1929) already called attention to the fact stated above with regard to *Sinanthropus* jaw A II. The occurrence of the fossa subalveolaris anterior in recent man is connected with the entire complex of changes produced by the reduction of the frontal part and the formation of the chin.

Torus mandibularis: As already stated in an earlier publication on *Sinanthropus* (Weidenreich, 1935) the inner surface of the alveolar process of the left half of the mandible G I is distinguished by a special formation (Plate IV, figs. 2, 3; Plate X, fig. 1). Approximately in line with the alveolar septum between P_1 and P_2 a considerable oval swelling arises and terminates exactly at the alveolar border. A second but smaller swelling is situated in front of this in line with the septum between C and P_1 and further forward there are two very small elevations at the same site between C and I_2, and I_2 and I_1. Behind the main swelling there is another irregular, moderate elevation of the surface which occupies the whole alveolar part as far as the third molar, which gradually increases in height. Here it assumes more the character of a roughness furrowed within certain intervals by fine wrinkles which run parallel in slightly oblique direction down and backwards to above and forwards. The main swelling between P_1 and P_2 is about 1.0 mm high, its mesio-distal length being 8.8 mm, the swelling between C and P_1 has the same height, but its length is only 5.7 mm. In downward direction the extent of the two swellings is 7.7 mm and 8.2 mm respectively. The two swellings behind the incisors represent small grain-like tubercles of about 3.5 mm length and 1.0 mm breadth. As to the right half of this mandible there is only a small fragment of the alveolar process in the region behind P_1 and C preserved and this piece contains the same formation, namely a part of the swelling behind C and P_1 and a part of the succeeding one behind P_1 and P_2, both separated by a deep and narrow wrinkle (textfig. 39). In size and extent this swelling looks absolutely like the corresponding formation of the left half of the mandible.

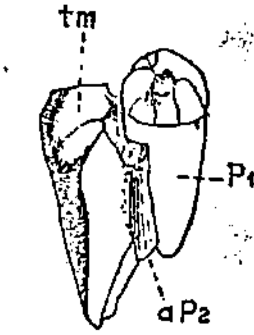


Figure 39. "Natural" cross section through the right side of the torus mandibularis of the male *Sinanthropus* G I medial to the alveolus of P_2. Abbreviations: — aP_2, alveolus of P_2; P_1, first premolar, tm, torus mandibularis. Natural size.

In jaw H I the same peculiarity as in jaw G I is recognizable (Plate VII, figs. 2 and 3; Plate X, fig. 2 and textfigure 36), the only difference being that the whole formation is not so strongly developed as in the latter. Both C-P_1 and P_1-P_2 swellings are very distinct, they are roundish, well limited and rather isolated tubercles of about 4.0 mm diameter. Their upper border continues with a sharp striation running forward obliquely. In front of the first larger swelling there is a very small grain-like tubercle inward of the septum between I_2 and C. The posterior protuberances in the region of the molar are indistinct irregularities more limited to the alveolar border, with the latter forming a special, thickened crest in line with the middle of M_3.

Jaw A II has a somewhat different appearance (Plate I, figs. 2, 6; Plate X, fig. 3 and textfigure 38), the swelling being more restricted to the region of the molars. The swelling in the region of the premolars seems to be reduced to a low and flat, longish elevation. All protuberances situated more in front are completely absent.

The relief of the alveolar part is characterized by the presence of a great deal of *striations which run in oblique* direction and border correspondingly moderate elevated areas.

In jaw H IV (Plate IX, fig. 10) the region in question is slightly damaged so that the conditions are not so easy to survey as in jaw A II. In addition the whole jaw behind M_1 is broken off. Nevertheless, it is quite apparent that jaw H IV resembles jaw A II very closely. A light swelling in the region of M_1 is evident and there is the same kind of striation running from its anterior and upper end to the premolars as in the cases of jaws H I and A II.

Unfortunately, all juvenile jaws of *Sinanthropus* are more or less damaged at the site of the swellings. In jaw B I (Plate II, figs. 2, 3) the whole upper part of the alveolar process is missing and was restored with artificial material by Davidson Black. In jaw B III (Plate VIII, figs 9, 12) which is of about the same age as B I the only sign of an irregular surface is a small oblique ridge on the inner side of the deciduous first molar. The jaw B V (Plate IX, figs. 2, 4) which is a little more advanced in age than B I and B III also reveals a faint striation at the boundary between P_2 and the first deciduous molar.

Thus we are dealing with two types of the particularity in question in *Sinanthropus*. One is the *"striation type" represented by striations with intermediate moderate elevations located in the region of the molars.* The other type is the "tubercle type" characterized by larger and more distinct swellings in the region before the first molar; from here these swellings extend upward more or less isolated, or more correctly, they are separated from each other by wider furrows than in the striation type. Furthermore, they rapidly decrease in size so that the swelling of P_3 is the largest and that of I_1 the smallest one. Whereas the tubercle type always occurs in combination with the striation type, the latter may occur independently. All the mandibles of *Sinanthropus* recovered so far show the striation type, the tubercle type occurring in its characteristic appearance only in the male jaw G I and in the female jaw H I.

To realize the significance of that particular phenomenon two factors are of special importance. As described above the posterior part of the inner surface of the alveolar process is divisible into two parts, an upper, larger and rough one, and a lower, smaller and smooth one, the linea mylohyoidea marking the boundary between them. Textfigure 36 demonstrates that the rough part embraces the area of the striations as well as that of the swellings, that is to say, that the former is nothing else but a regular and specific differentiation of the posterior rough part, whereas the swellings are to be considered as exaggerated irregularities of the same character occurring occasionally. This interpretation is supported by another fact. The small piece of the right half of jaw G I (textfig. 39) is broken just across the main swelling between P_1 and P_2 representing in this way a natural section through the body of the jaw. This reveals that the swelling is caused exclusively by a thickening of the compact inner zone (tabula interna) of the mandible without any participation of the spongy substance (textfig. 39).

Both these circumstances prove that the described peculiarities of the inner surface of the alveolar process are a mere differentiation of the superficial part of the bone and do not show any connection whatever with the internal structure of the mandible nor are they related with any special appearance of the teeth. However, the real reason why this peculiarity is so highly important is the fact that it is found in exactly the same degree of development in recent man. Danielli (1884) was the first to call attention to the occurrence of "hyperostoses" in the mandibles of Ostiaks and Lapps on the inner side of the alveolar process; Jören Hansen (1895) observed it as a special feature of Eskimo mandibles. Fürst (1908) subsequently examined this formation more thoroughly in Eskimos and termed it "torus mandibularis." According to him it consists of one eminence or a series of them which may vary but in general show a distinct and regular arrangement. The highest of the single protuberance is usually located on the inner side of P_2. The protuberances throughout are composed of compact bony substance.

Fürst and Hansen (1915) later gave a more detailed description of it. Hrdlicka in particular made repeated studies on this particularity in Eskimo jaws (1910, 1930b). In the meantime Hooton (1918) found the torus in question also in the jaws of the Icelander and considered it an Eskimoid character. According to him the usual concentration of this bony reinforcement here is restricted to the region between the canine and the first molar.

The most recent investigation of this formation has been made by Schreiner (1935) with special reference to its occurrence in Lapp jaws. This author calls the hyperostosis of the alveolar arch the "tori alveolares mandibulæ" and describes them as follows: They may exhibit all degrees of development beginning with a thickening of the compact bony substance only palpable but not clearly visible and ending with an enormous hyperostosis which may be determined as an osteoma. The location of this torus usually corresponds to the part of the alveolar process between C and $P_3 — M_1$. The torus shows the same or about the same extent on both halves of the jaw as a rule. The hyperostoses corresponding to the incisors, the canine and the premolars are generally located slightly below the alveolar border, but they may reach it in the case of stronger development. The hyperostoses corresponding to the molars, especially to the two posterior ones, usually have a wrinkled surface and arise wall-like from the border. They never have the same largeness as the more anterior hyperostoses. Schreiner gives the following table demonstrating the anterior and posterior limits of the torus in 100 jaws:

	I_1	I_2	C	P_1	P_2	M_1	M_2	M_3
Anterior limit	1	4	58	24	7	1	3	2
Posterior limit	-	-	-	9	43	25	10	13

The pictures reproduced by Fürst and Hansen, Hooton, Hrdlicka and Schreiner reveal that the so-called hyperostoses found in the jaws of Eskimo and Lapp correspond entirely with regard to their location, arrangement and appearance to the formation in *Sinanthropus* described above.

I was able to complete the statements of the above mentioned authors by ascertaining the occurrence of the same phenomenon in recent and Prehistoric Chinese. However, I wish to emphasize on the different appearance of the formation in *Sinanthropus*: the striation type and the tubercle type. The first mentioned type occurs more frequently than the second which is, as stated above, combined with the other. Of course, the variation in recent Chinese is great so that it is not easy to give a precise description which could apply to all occurring cases. The striation type is illustrated in textfigure 40, the jaw belonging to a North Chinese adult male individual. It corresponds to that of *Sinanthropus* A II. The combined striation and tubercle types are represented by textfigure 35. The jaw reproduced in the latter also belongs to a North Chinese adult male individual. It is evident that in this individual the more pronounced swellings of the anterior part are nothing else but a continuation of the elevations of the molar region exactly as in the *Sinanthropus* jaw H I (compare textfigs. 35 and 36). In Plate X, fig. 4, another North Chinese adult male individual is illustrated in which it is evident that the tubercles and striations bear entirely the same characteristics as those of *Sinanthropus* jaw H I (Plate X, fig. 2). As stated by the above mentioned authors, it occurs at times that all of the various hyperostoses or at least one or several become hypertrophic and form more or less large globular protuberances which project far inward without passing over the alveolar border appreciably. In Plate X, fig. 5, such a case is illustrated of a jaw belonging to a Prehistoric (Æneolithic) Chinese. The hypertrophic torus refers here to that between P_1 and P_2, the anterior ones being only grain-like, the posterior ones showing the striation type. In this case the crowns of the teeth are worn almost up to the neck. On the outer side there are some indications of pyorrhoeic processes but this appears to be more the consequence of the extraordinary

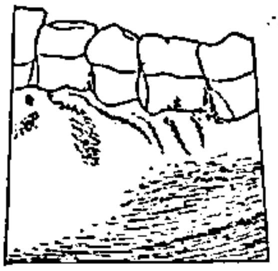


Figure 40. Prominentia alveolaris—striation type of a modern North Chinese man (no. 133). Natural size.

attrition rather than that of the abnormal alterations of the inner bony wall of the jaw, for in other cases where the attrition is normal and pathological changes do not exist the torus may be enlarged to the same extent.

This enlarged torus enabled the author to study its structure in detail. A cross section was made in which was found that the whole protuberance was of a very hard and ivory-like consistency. It is strictly confined to the compact layer of the inner side of the jaw (tabula interna) and not mingled with any spongy substance at all (textfig. 41). Microscopic examination reveals that it consists throughout of a highly dense lamellar bone provided with very scanty and narrow Haversian canals. A comparison of the cross section of the jaw of a modern Chinese (textfig. 41) with that of *Sinanthropus* jaw G I (textfig. 39) proves that there is no difference in the character of the two structures. Therefore the tori mandibulares in *Sinanthropus* and recent man are completely identical in their position, appearance and internal structure.

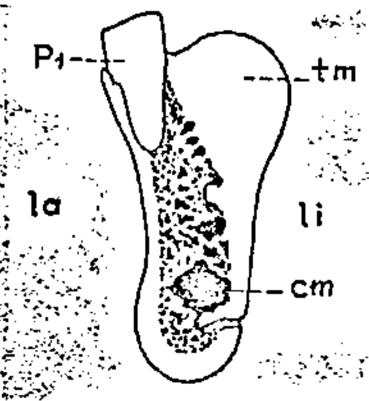


Figure 41. Cross section through the exaggerated torus mandibularis of the mandible of a prehistoric Chinese (Kansu 241/6) in line with P_1. Abbreviations— la, labial; li lingual; cm, canalis mandibularis; P_1, first premolar; tm, torus mandibularis. Natural size.

As to the torus of recent man the most remarkable fact seems to be its restriction to certain groups of mankind. Table IV shows the frequency and distribution of the torus among the various groups, the figures being taken from the publications by authors cited.

This table requires certain comment. The distinction applied for classification of different degrees of development of the torus is too uncertain, in addition it does not refer to the two types, namely the striation and the tubercle type. It seems that all the figures given by the respective authors refer exclusively to the tubercle type and that those entered under the heading "very pronounced" and "pronounced" cases correspond to the exaggerated forms as suggested by the illustrations. In any case the list shows clearly that the torus is much more characteristic of the Mongolian than of the other races. The second striking factor is that the percentage of its occurrence is slightly higher in prehistoric or historic man than in present man.

I undertook to make a corresponding study on the Chinese material at my disposal. As regards the tubercle type, the large tubercle between P_1 and P_2 was present in 15%, the smaller anterior one between C and P_2 only in 5%, while the striation type in the region of the molars is more or less distinctly recognizable in about 40%. These figures refer to Northern Chinese of today. However, in the Æneolithic material the tubercle type occurs much more frequently, amounting to 25% which includes forms only slightly developed.

These figures together with those referring to Japanese and Scandinavian (see list) show that the torus mandibularis has been more frequent in prehistoric and historic times than today. As this decrease takes place without any connection to a special group, it seems that we are dealing with a real reduction of the formation. Thereby its occurrence in *Sinanthropus* has become of special significance. For there is no doubt that the torus in *Sinanthropus* and that in recent man are identical, the former corresponding to the "moderate" or "pronounced" types of the respective authors. Of *Sinanthropus* we have four adult mandibles two of which show the tubercle type, the other two the striation type. Even if we decided to omit the latter type because figures necessary for an accurate comparison with recent man are missing, the torus (tubercle type) in adult *Sinanthropus* occurs in one half of the specimens, and including the striation type its occurrence is to be found in all of them. This is to say that *Sinanthropus* approaches that group of mankind of today which is characterized by the peculiarity of a torus mandibularis.

TABLE IV.

Occurrence of the torus mandibularis in recent man

Group	Total percentage	Average as given by the authors	Authors
Eskimo (Greenland)	85.0		Fürst and Hansen (1915)
Eskimo	87.0		Hooton (1918)
Eskimo (Western):			
Adult Male	79.5	69.7	Hrdlicka (1910)
Adult Female	60.0		
Children	24.2		
Eskimo	97.0		Allen (1890)
Eskimo Male	62.5	41.7	Schreiner (1935)
" Female	33.3		
Ostiak	31.4		Danielli (1884)
Lapp	29.4		Danielli (1884)
Lapp	30-35		Fürst and Hansen (1915)
Lapp:			
Adult Male	26.8	32.5	Schreiner (1935)
Adult female	38.8		
Children	12.9		
Icelander	67.9		Hooton (1918)
Ainu	24.0		According to Japanese publications kindly communicated by Dr. Akabori
Japanese: Neolithic	62.1		
Modern Japanese (Kinai)	14.0		
" Japanese (Kranto)	—	9.4	
American Indian (South California)	4.3		Hooton (1918)
Scandinavian:			
Prehistoric and Middle Age	17.0		Fürst and Hansen (1915)
Later periods	12.0		
Norevgian:			
Middle Age Male	24.0	17.0	Schreiner (1935)
Middle Age Female	10.0		
Later periods: Male & Female		12.0	
Italian	3.3 (slight)		Hooton (1910)

All of the earliest investigators of the torus have noted its very close relation to the Mongol races. The figures given above for Japanese and Chinese serve to complete this observation. Yet, as seen in Table IV the occurrence of the torus is not at all confined to this racial group. It may be questionable as to what extent we should be justified in ranging the Lapps and the Ainu within the Mongol group. However, the Icelanders and Scandinavians would oppose any attempt toward forming such a subsumption. On the other hand the fact is significant that the torus has only been found sporadically in other populations, as for instance in the jaw of Italians, Hungarians, Slovenes, ancient Peruvians, American Indians. In all the existing literature no mention is made of its occurrence in Negroes, Malayans or primitive races like the Australians, Melanesians, etc. In the small collection of racial skulls at my disposal, I failed to find any indication of the existence of the tubercle type in the Australian jaws, however traces of the striation type have been observed in one of them. Among 38 mandibles derived from Moravian ossuaries one jaw exhibits the tubercle between P_1 and P_2 very distinctly on both sides and at the same time characteristic striations inside of M_1. The writer is pleased to be able to demonstrate the occurrence of the torus in living man. In Plate X, fig. 6, the floor of the mouth of an American woman is reproduced. On each of the inner side of the alveolar arches there is a large swelling just inside of C and P_1 which projects considerably and narrows the floor. It is covered by the gums which are smooth and light so as to appear to be very tightly attached to the bone. This feature corresponds to the absolutely smooth surface of the protuberance in the case of the Æneolithic Chinese (Plate X, fig. 5). A faint furrow on the surface of the swelling indicates that it consists of two parts, a larger posterior and a smaller anterior one. The subject remarked that her dentist called her attention to the presence of this particular formation which had never caused her any inconvenience. Her sister has the same peculiarity. The subject's family is of European origin, one branch coming from Ireland.

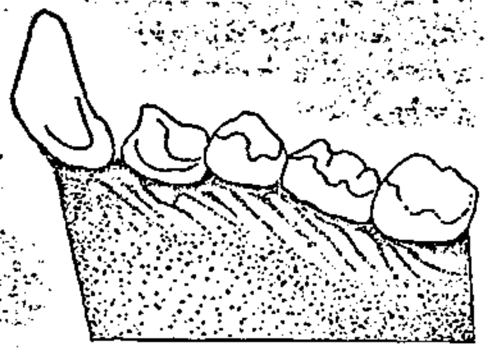


Figure 42. Prominentia alveolaris — striation type of the lingual surface of an adult male chimpanzee. Natural size.

The earlier authors have discussed intensively the significance of the torus, but as we know at present that the torus goes back to *Sinanthropus* and represents a very old morphological character of the hominid jaw, the entire question takes on another aspect. Firstly, it should be ascertained whether the same or at least a similar feature occurs in other primates. With reference to the anthropoids, the writer failed to observe anything that could be considered to be in direct relation to the tubercle type of *Sinanthropus*. Only in the jaw of a female orang was there found a unilateral, distinct, roundish swelling of the alveolar process inside of M_2 and a second elevation, very faint, and just palpable inside of P_1. On the other hand the striations of the molar region are very common in chimpanzee as well as in gorilla. In such cases we deal with a series of fine and narrow undulated furrows which occupy the upper part of the alveolar process from M_3 to I_1 and pass over its border to the brim of the alveoli so that the border looks like a ribbed pattern. The striation runs obliquely from below and backwards to above and forwards (textfig. 42). A comparison of textfigure 38 with textfigure 42 shows that the striations of chimpanzee are of the same kind as those of *Sinanthropus*.

It would be of great value if we had a better knowledge of the occurrence of the formation in question in the jaws of the Neanderthal group. But unfortunately none of the authors who described the original material paid any special attention to these formations so that we are entirely dependent on the hardly reliable casts to form a judgement on the actual conditions. Some of the mandibles of the Neanderthal group, for instance the adult jaw of Ehringsdorf and more especially the Krapina jaw I, exhibit irregular tubercles at the alveolar border scarcely directly comparable with the torus mandibularis. In revising my earlier remarks (1935) I come to the conclusion that the circumscribed swellings at the alveolar part between P_1 and P_2 on each side of the Ehringsdorf adult jaw correspond to the torus of *Sinanthropus* and that the same may be true for the swellings between P_1 and P_2 on the left side, and between P_2 and M_1 on the right side in the jaw of Spy I. Yet all the other peculiarities characterizing the torus in *Sinanthropus* and in recent man are absent. However, I have the impression that a striation of the molar region may exist in the Heidelberg jaw. In any case there is no jaw in which the torus is so well and typically developed as it is the case in *Sinanthropus* cr in the Mongolian group of recent mankind.

In discussing the torus in question most of the authors devote extensive descriptions to its significance. Frcm Fürst to Schreiner all agree that its formation is the result of mechanical causes. Hrdlicka (1910) remarked: "the hyperostosis is undoubtedly of functional origin, the result of extraordinary pressure along the line of teeth most concerned in chewing, yet its occurrence in infant skulls indicates that at least to some extent the feature is already hereditary in these Eskimo (Southampton Island)." But Hooton (1918) objected to the above, stating that in such a case it would be natural to expect the concentration of the bony reinforcement opposite the molars rather than opposite the premolars. The same author believes that primitive people must make more use of their teeth fcr mastication than those handling knives and forks, and that a strengthening of the symphyseal region would have been necessary in case the natural strength of the alveolar process and of the mandibular arch were not sufficient to withstand the strain directed medially in mastication.

I regret to be unable to agree with the views expressed by the authors quoted above. The mandible of a Prehistoric Chinese with an exaggerated torus as illustrated in Plate V, fig. 5, shows that all teeth are very badly worn off up to the neck. The degree of attrition increases from the anterior to the posterior teeth, but in all of them the attrition reaches down considerably more on the labial side than on the lingual side. This proves clearly that the pressure of mastication is much stronger on the outer than on the inner side, yet the torus, supposed to support the most affected part, is located on the opposite side. Even apart from this, I fail to understand how a relatively small swelling superposed on the outer layer of the bone, as seen in textfig. 41, could be able to strengthen the bone itself. This would be tantamount to an attempt of increasing the power of a wall to stand compression by a bay or a balcony at its facade. Furthermore, it would be hard to explain why this strengthening is restricted to certain groups of mankind and why in *Sinanthropus* it should be very strongly developed in jaw G I, which in itself already represents an extraordinary bulky specimen, while the torus is much weaker in the like-wise smaller jaw H I. In other words, the extent and the thickness of the torus is obviously more correlated with the actual robustness of the jaw than with the need of strengthening.

Schreiner (1935) adds still another argument by way of possible explanation. He does not contest the possibility that chewing may produce proliferations of the bone by increased pressure, but he believes that an abnormally strong irritability may be the presupposition for such a reaction. Schreiner deduces this increased irritability from Hooton's observation, namely that the torus mandibularis in Eskimo was frequently found to be combined with a torus palatinus, a combination which Schreiner was able to confirm in Lapps also. The occurrence of the torus mandibularis and torus palatinus respectively is recorded as follows:

	torus mandibularis	with torus palatinus	without torus palatinus
Eskimo (Hooton)	81%	56.6%	43.4%
Lapps (Schreiner)	32.5%	82.0%	18.0%

Unfortunately, among the *Sinanthropus* material there are no parts of the skull containing the preserved palate so that we are confined to recent man for the study of the special conditions of this feature and its relation to the torus mandibularis. Firstly, it should be noted that no real correlation between the occurrence of the torus mandibularis and the torus palatinus can be ascertained, inspite of the coincidence quoted above. This will become obvious by comparing Hooten's figures on the frequency of both features in Italians, American Indians and Japanese. The torus palatinus was found to occur in 32.5% of Italians and in 60% of American Indians, while the torus mandibularis occurred only in 3.3% of the first group and 4.3% of the second group. The same results were obtained from observations made on the recent Japanese material. Akabori found the torus palatinus present in 43.7% of recent Japanese and the torus mandibularis was noted in only 9.4% (compare Table IV).

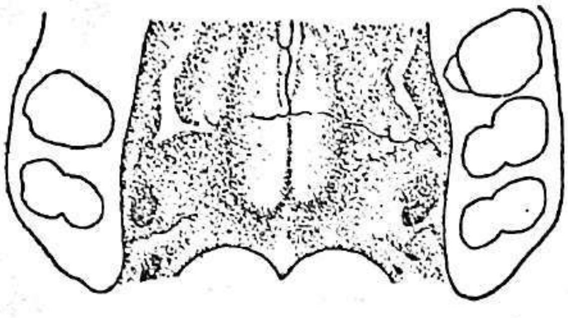


Figure 43. Torus palatinus of a modern European (L. Austria, No. 14721). Natural size.

Schreiner believes that the pressure of mastication is also to be considered as the real cause for the formation of the torus palatinus. The writer is rather sceptical toward this suggestion. The torus palatinus, if well developed, is always situated along the midline at the junction of the palatine bone and maxilla (textfigs. 43, 44), the strongest portion falling to the palatine bone. However, the horizontal part of this bone is the thinnest of the whole palate and therefore could not transmit any pressure. Furthermore, it is evident from the structure of the torus palatinus that it is entirely impossible for it to serve the special purpose attributed to it; a cross section (textfig. 44) reveals that the main part is formed by spongy substance with appreciably wide meshes and that only the outer layer consists of compact bone.

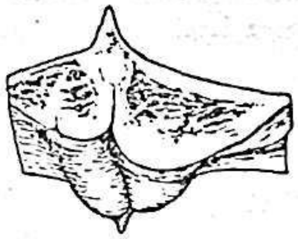


Figure 44. Cross section through the torus palatinus of a modern European (L. Austria, No. 14706). × 2.

Thus I come to the conclusion that the torus palatinus is to be considered as an independent formation without any direct connection with the torus mandibularis. In confirmation of such an assumption is the fact that a feature like the torus palatinus is not uncomnon in *Macacus rhesus*. In a male specimen of our collection a very distinct roundish elevation with a smooth surface runs along the middle line from the posterior nasal spine to the incisive foramen, the longitudinal suture of the palate halving the torus (textfig. 45). The skull exhibits no other exostosis or any other abnormality. In another Macacus specimen the same formation is recognizable even though not to such an extent. It is a remarkable coincidence, that the well preserved skull of fossil Macacus recovered quite recently from Locality I of Choukoutien also shows a short and small but very distinct torus palatinus in the palatine portion (textfig. 46).

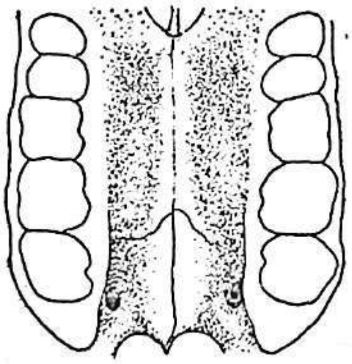


Figure 45. Torus palatinus of a recent *Macacus rhesus* (No. 260) Natural size.

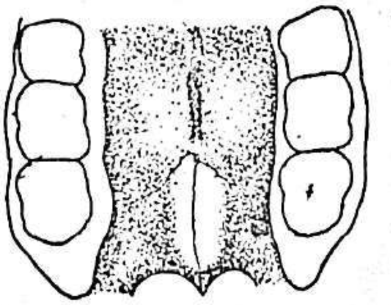


Figure 46. Torus palatinus of a fossil Macacus (Locality I of Choukoutien). Natural size.

To return to the torus mandibularis Schreiner found that there is a great variability in the frequency of its occurrence within the various tribes of Lapps ranging from 53.3% in Kistrand Lapps to 16.7% in Neiden Lapps. The same holds good for the torus palatinus. Schreiner is inclined to trace these differences to variations in the irritability of the bone tissue caused perhaps by an exclusive diet or by scarcity of food (avitaminosis).

In view of the fact that a torus mandibularis of exactly the same type as that of recent man already occurs in *Sinanthropus*, all attempts are erroneous which interpret this formation as a relatively late special acquisition and as a consequence of a particular diet or a peculiar manner of eating or a special irritability of the bone substance within a certain population. It rather seems beyond doubt that we are dealing with a primitive hominid character which may have been more or less variable since its first appearance. That the same is true for the torus palatinus is proven by its occurring in the fossil as well as in the recent Macacus. Both statements therefore place the question as to the significance of the two tori back to remote times.

The writer believes that the formation of the striation type of *Sinanthropus* depends upon the attachment of the mucous membrane to the surface of the bone. The connection between the two tissues in this region is very firm. Therefore it may be that connective tissue fibers in the areas of the greatest strain are inserted into fine furrows of the bone surface. As to the tubercle type, that is to say, the real torus mandibularis, I am inclined to accept the suggestion that the protuberances are pillars left during the reduction which the formerly much bulkier alveolar process has undergone in the course of human evolution. The same explanation may hold good for the torus palatinus. I should not be surprised if that formation would also be found in *Sinanthropus*. Compared with the bony palate of anthropoids, that of recent man is very thin. In the gorilla for instance large air sinuses intervene between the oral and the nasal layers of the palate. It is probable that the reduction of the whole mastication apparatus also causes a rarefaction of the palate bone, with the exception of the longitudinal junction where the original thickness remains preserved from unknown causes.

Be that as it may, the significance of the torus mandibularis in recent man rests on the fact that its occurrence is chiefly confined to certain groups of mankind. In these groups it has retained its ancient character as realized in *Sinanthropus*, whereas it is entirely or partly absent in other groups. I do not consider it a failure to bring the former groups in closer relation to *Sinanthropus*. The groups listed in Table IV are arranged according to the sequence of the frequence of the torus as follows:

Eskimo (after the various authors)	42-97%
Icelander	68%
Neolithic Japanese	62%
Lapps	32.5%
Ostiak	31%
Ainu	24%
Prehistoric Chinese	23%
Prehistoric Scandinavian	17%
Recent Chinese	15%

Most of these groups belong to the Mongol race or at least are closely related to it like the Lapps and the Ainu. Of course, the racial character of *Sinanthropus* cannot be judged on the basis of racial characteristic of today. The fact that *Sinanthropus*, the oldest hominid is found on Eastern Asiatic soil, is taken by the writer as proof of its close relationship to the groups listed above. In any case this relationship must be closer than that between *Sinanthropus*, Australian, Negroes and most of the European or West Asiatic racial groups.

However, there is one opposing factor. The Icelander and the Scandinavians do not fit into the diagram outlined above. The solution of this problem will have to be left for the future. It may be that in early times a part of the original population of the North European countries had some connection with the Asiatic Mongol branch derived from *Sinanthropus*. The occurrence of the torus in the Ainu, a tribe which many authors consider as a relic of a widespread Northern Eurasian racial group. supports this hypothesis.

5. The lower margin of the body — fossa digastrica

The lower margin of the mandible in recent man when viewed from below shows a very characteristic feature. It begins thinly at the ramus, becoming thicker to attain the greatest diameter in the level of M_2, decreasing gradually up to the level of P_2, and reversing to a slight increase to form the frontal part which keeps the same thickness. In anthropoids the course of the bordet is different. The first thickening is kept without any limitation and continues to the far projecting frontal part. Only in those cases where the tuberculum platysmaticum posterius is strongly pronounced it projects considerably sidewards. *Sinanthropus* has its distinguishing character in this respect. Being thin at the ramus the margin gradually becomes thicker and attains the greatest diameter in the level of P_1. The decrease beyond this mark is very slight (Plate II, fig. 4, Plate IV, fig. 4, Plate VII, fig. 4, Plate VIII, fig. 3). The jaw of the Neanderthal group resemble those of *Sinanthropus*.

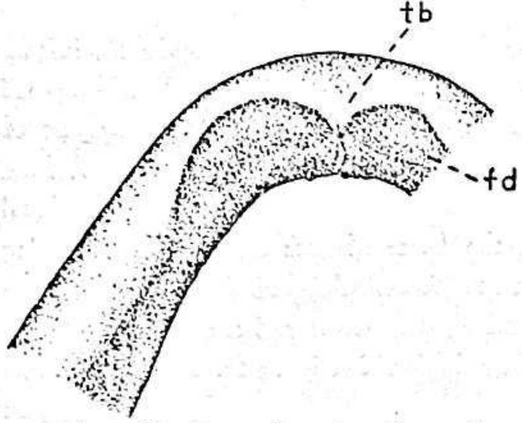


Figure 47. Fossa digastrica of a modern Australian native (No 68). Abbreviations:— fd, fossa digastrica; tb, trigomum basale Natural size.

More important than this general appearance of the lower margin is the shape of the basal arch and the feature of the digastric fossa. The first will be discussed below. As to the latter, we owe very accurate and detailed descriptions to Toldt (1915) and H. Virchow (1920). Toldt differentiates mandibles with thin basal borders from those with thick ones. In the first the fossæ should lie entirely on the posterior surface of the frontal part, in the latter on the basal surface. Such a description is important but not always correct when applied to the jaws with thick borders. For there are many thick jaws in which the fossæ also occupy more or less the posterior surface, which is especially true for Australian jaws. Generally speaking, it is characteristic for recent man that the digastric fossæ are not situated on the base itself but on the slope leading to the posterior surface, that is to say, they are not directed immediately downward but at the same time backward (textfig. 47 fd). In all cases pertaining to recent man the anterior brim of the fossa constitutes at least the edge of the border of the jaw.

The second characteristic of the fossa in recent man is its shape. The fossa represents approximately an oval depression. According to Virchow the long diameter (mesio-distal) is 11-19 mm and the short (labial-lingual) 5.0-7.5 mm. Thus the average would be 15 mm and 6.25 mm respectively. Virchow emphasizes the fact that the region in question is not always a "fossa" but occasionally a mere "area" which means that it can be more or less flat. The anterior and medial border of the area projects in all cases quite strongly, while the posterior border and still more the lateral border continue to the adjacent surface without a distinct limit. Therefore, the character of the surface alone defines what belongs to the area. Compared with the surrounding parts the field of attachment of the digastric muscle is rough, the roughness being especially pronounced toward the anterior and mesial parts.

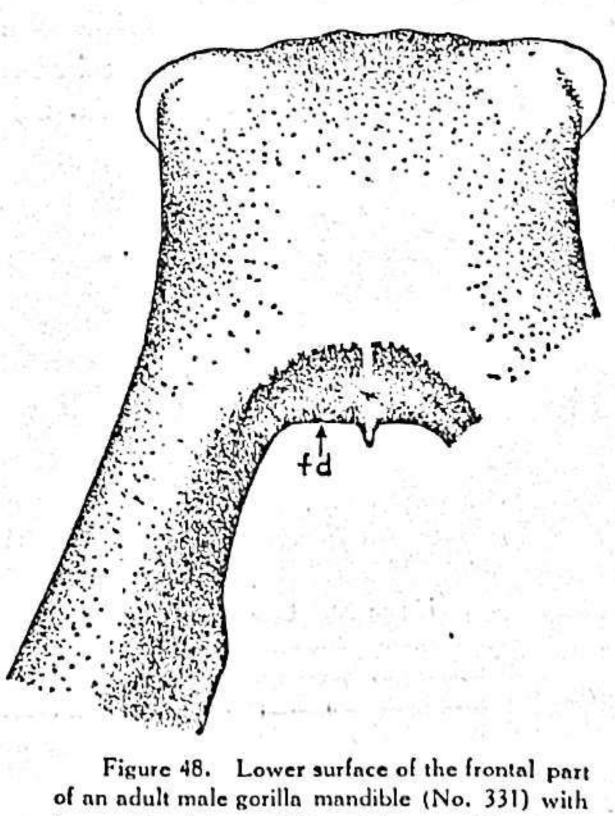


Figure 48. Lower surface of the frontal part of an adult male gorilla mandible (No. 331) with fossa digastrica. Abbreviation:— fd, fossa digastrica. Natural size.

The fossæ of each side are separated by a triangular interspace known as the trigonum basale according to Toldt (textfig. 47 tb). Its breadth varies. The vertex of the trigonum is generally transformed into a small spine or crest — the spina interdigastrica (Klaatsch). Its base is occasionally limited by a faint cross furrow which H. Virchow named "sulcus praedigastricus." The anterior side of this furrow is formed by the base of the mental trigonum which is more pronounced in such cases (compare above, p. 31).

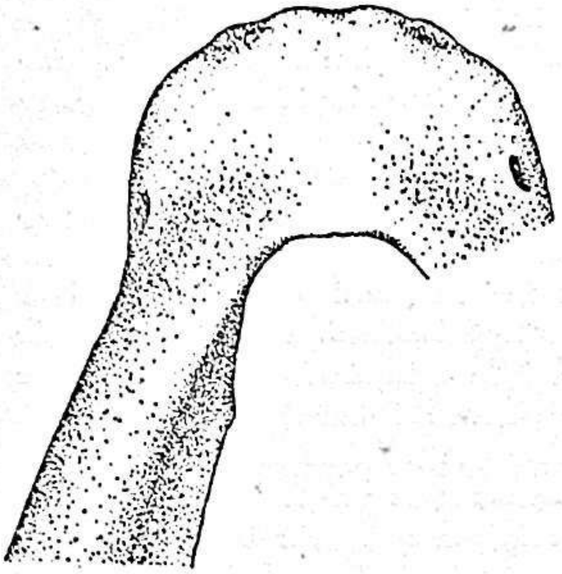


Figure 49. The same view as in fig. 48 of an adult female orang mandible without any indication of a fossa digastrica. Natural size.

To begin with the anthropoids, a fossa digastrica is well developed in gorilla and chimpanzee, even though its size and appearance vary. In the former (textfig. 48) the fossa occupies the inferior side of the torus transversus inferior (basal plate). It is separated from the lower smooth surface of the anteriorly projecting part of the jaw by a rough and extensive brim, the whole area of the fossa being remarkably deeper situated than the other surface. A basal trigonum does not exist, the fossæ of both sides almost bordering upon each other. The conditions observed in chimpanzee are similar, but the fossæ generally are longer and narrow than those in gorilla. Orang takes a special position in so far as that the fossa is completely absent, with the smooth surface of the projecting part of the jaw reaching the posterior border (textfig. 49).

In *Sinanthropus* the region in question is best preserved on the right side of H I (Plate VII, fig. 4; textfigs. 50 and 51). The fossa is represented by a very long and relatively narrow flat area. It lies entirely upon the horizontal margin, its anterior border being slightly elevated and projects outward. This feature is due to the development of the area platysmatica and the tuberculum anterius (tma), both of which have been described above, with the anterior part of the digastric fossa extending to the inferior side of this protuberance. In this way the anterior border of the fossa coincides with the somewhat projecting anterior border of the mandibular

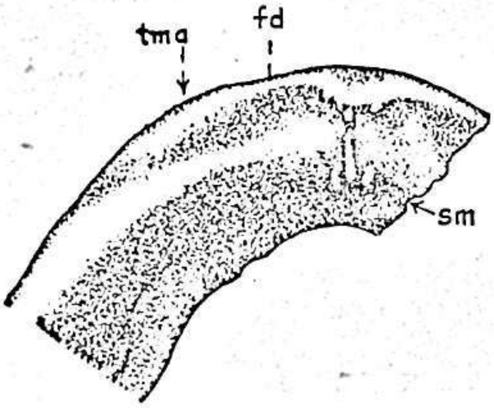


Figure 50. Lower margin of the mandible female *Sinanthropus* H I. Abbreviations:— fd, fossa digastrica; tma, tuberculum marginale anterius; sm, spina mentalis. Natural size.

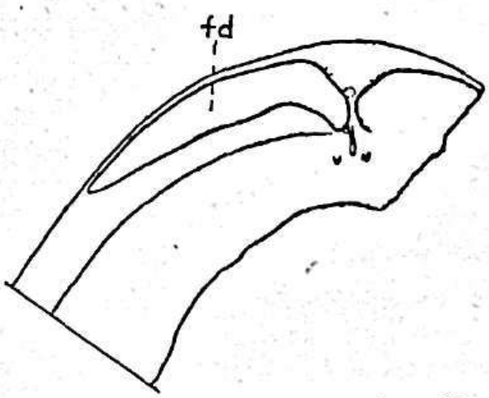


Figure 51. A sketch of fig. 50. indicating the boundary of the fossa digastrica. Abbreviations:— fd, fossa digastrica. Natural size.

margin proper. The mesial border of the fossa reaches the symphysis, the distal border the line of the distal root of M_1. The surface of the fossa is not smooth but undulated, the anterior third being slightly deepened. This part at the same time is smoother than the posterior two thirds. The length of the fossa is 27 mm, the breadth in the widest area 7.7 mm. The left digastric fossa is only preserved to an extent of 12 mm, this particular part not showing any appreciable difference when compared with the right fossa. Textfigure 51 illustrates the exact position and extent of the left fossa, the contours being marked by a heavy line.

The two fossæ are separated from each other by a triangular elevated area. This basal trigonum is continuous at the front with the lower border of the tuber symphyseos as described above, and tapers off toward the mental spine (sm). Here there is to be found a very small interdigastric spine which is directed downward and backward. The distance of the two fossæ measured in the narrowest area is 7.2 mm. The longitudinal axis of the two fossæ together form an angle of approximately 126°.

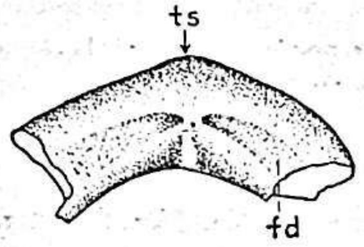


Figure 52. Lower margin of the symphysis part of the mandible of *Sinanthropus* child B I. Abbreviation:— fd, fossa digastrica; ts, tuber symphyseos. Natural size.

In *Sinanthropus* jaw G I (Plate IV, fig. 4) the distal end is preserved to a length of about 5 mm. As in jaw H I the fossa lies entirely on the basal border of the jaw and resembles also in all other details the jaw just mentioned.

In *Sinanthropus* jaw A II (Plate I, fig. 4) the distal part of the right fossa is preserved to a length of about 15 mm. It is situated entirely on the basal margin of the mandible, its anterior as well as posterior borders coinciding with the corresponding borders of the jaw. The area is smooth and slightly deepened. Anteriorly and posteriorly from the area the margin is broken off.

Among the juvenile jaws of *Sinanthropus*, specimen B I has the best preserved fossæ (Plate II, fig. 4; Plate VIII, fig. 1; textfig. 52). According to the narrowness of the basal margin the fossa is narrow and long. It is situated entirely on the margin, the anterior border being slightly elevated. To the anterior end the whole area rises and the fossa itself is deepened and moderately rough. The two fossæ are separated by a narrow crest like an elevation bearing two very fine spines. In jaw B V the greatest part of the right fossa is preserved (Plate IX, fig. 5; textfig. 53). It occupies the whole basal margin, both its borders corresponding to those of the respective jaw. In the juvenile jaw B IV (Plate VIII, fig. 12) the fossæ as much as they are preserved show the same appearance as those in jaws B I and B V.

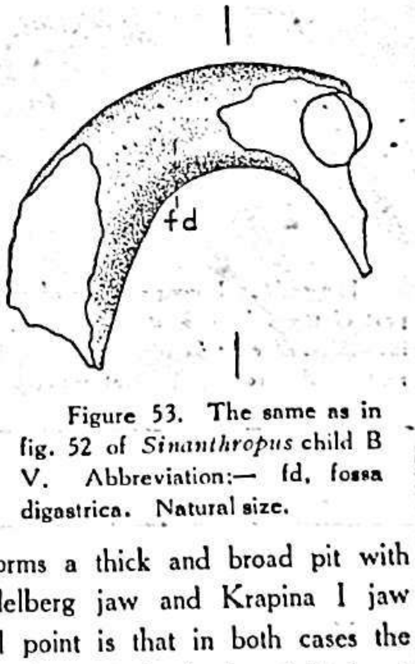


Figure 53. The same as in fig. 52 of *Sinanthropus* child B V. Abbreviation:— fd, fossa digastrica. Natural size.

Toldt (1915) made a careful investigation of the basal zone of the Neanderthal mandibles. He found that it varies in the same way as in recent man, the digastric fossæ being situated in a more or less horizontal plane. According to that author the fossa of the Heidelberg jaw reaches the anterior surface of the jaw, but the fossa itself inclines backwerd not inconsiderably. H. Virchow (1920) made the statement that within the Neanderthal group the fossa always forms a thick and broad pit with a strongly projecting anterior border. Textfigures 54 and 55 represent the Heidelberg jaw and Krapina I jaw respectively. The drawings for them have been made from casts. The essential point is that in both cases the fossæ (fd) when compared with those of *Sinanthropus* (textfig. 50 fd) are shifted to the posterior border of the basal margin and inclined downward so that they partly lie on the posterior surface of the jaw as is the rule in recent man. The Piltdown jaw reveals quite a special appearance in this respect (textfig. 56). As Friederichs (1932) has shown

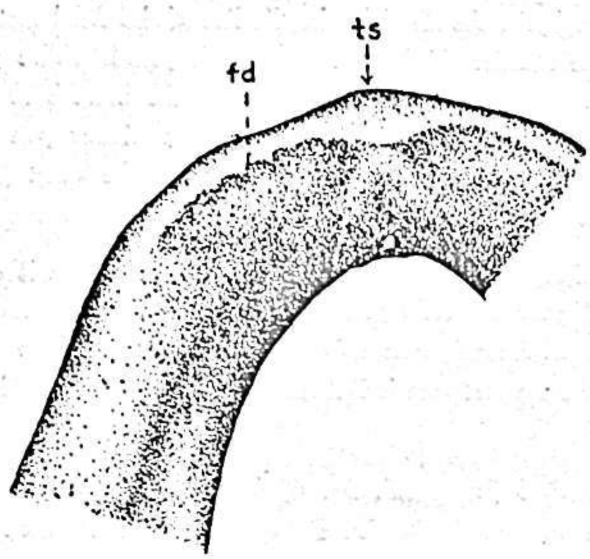


Figure 54. Lower margin of the Heidelberg mandible (with the defect restored). Abbreviations: — fd, fossa digastrica; ts, tuber symphyseos. Natural size.

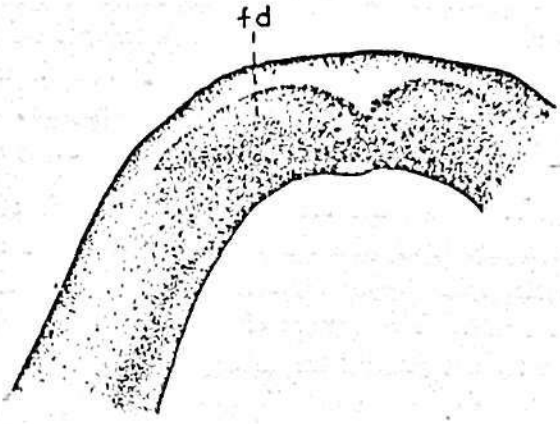


Figure 55. Lower margin of the mandible of Krapina I. Abbreviation:— fd, fossa digastrica. Natural size.

this jaw resembles almost completely that of a female orang. Like in the latter (compare textfig. 56 with textfig. 49) a digastric fossa is absent in the Piltdown specimen, a real basal margin does not exist but the whole part continues without any boundary line directly along the ape-like projecting surface of the mandible.

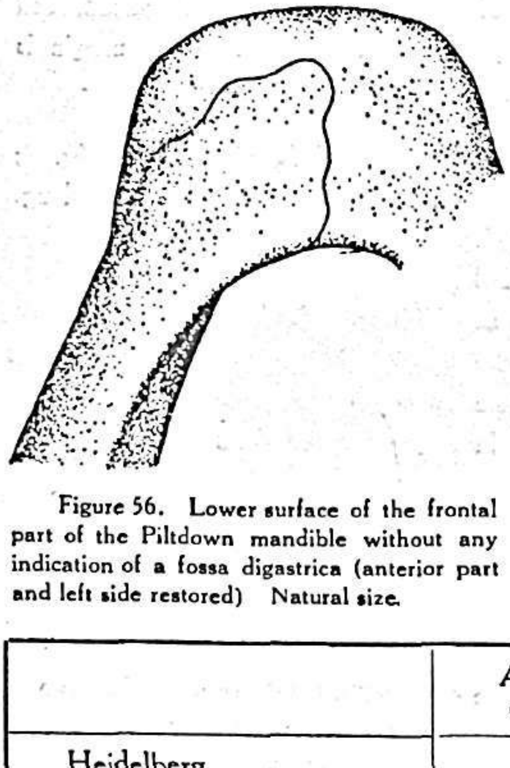


Figure 56. Lower surface of the frontal part of the Piltdown mandible without any indication of a fossa digastrica (anterior part and left side restored) Natural size.

The region of the digastric fossa of *Sinanthropus* exhibits some characteristic features. The most important of these is that the fossa occupies the basal margin proper in its whole extent, the anterior and posterior limits of the fossa coinciding with the corresponding borders of the basal surface. This appearance is clearly pronounced in the adult as well as in the juvenile individuals. The jaws of *Sinanthropus* thereby differ from those within the Neanderthal group in which the fossa has moved backward and upward causing it to be situated partly on the posterior surface. This tendency is still more accentuated in recent man.

Another significant character of the *Sinanthropus* fossa is the relation between its length and breadth. These measurements according to Virchow (1920) and Schoetensack (1908) are as follows:

	Anterior-posterior diameter in mm	labial-lingual diameter in mm	Index
Heidelberg	24 (22 and 26)	7.5	31.3
Krapina H	32	9.0	28.1
Krapina I	22	10.0	46.7
Le Moustier	20	8.0	40.1
Ehringsdorf (adult)	24.5 (23 and 26)	8.0	32.7
Recent Man	15 (11-19)	6.25 (5.0-7.5)	41.6
Sinanthropus H I	26.9	7.7	28.7

As to the feature of the basal trigonum in *Sinanthropus* there is no difference worth mentioning in comparison with that of the Neanderthal group.

The shifting of the fossa from the basal surface to the posterior one in the course of evolution is only a part of the general transformation of the whole frontal region of the mandible depending upon the retraction and reduction of the alveolar process on the one hand and upon the increase in height of the basal part on the other. This question will be discussed again below.

B. THE RAMI OF THE MANDIBLE.

1. The lateral surface.

Earlier in this publication (p. 23, ff.) I referred briefly to some of the details of the surface, and it is understood that there is no clearly defined demarcation between the rami and the body. The anterior border of the ramus is continuous with the oblique line and the posterior end of the latter with the lateral protuberance. This protuberance in turn proceeds downward and thereby forms a swelling which corresponds to approximately the anterior border of the masseter and delimits from the body the area to which this muscle is attached. At the lower margin that swelling is continuous with the torus marginalis described above. The surface of the ramus is here represented by a formation situated posteriorly from all the thickened parts of the body and often appears as a more or less pronounced depression bordered by the lower and posterior margin of the thickened ramus which is even turned up like a hook — the angle of the mandible. In such cases the masseter takes its origin from a real "fossa masseterica." Yet occasionally no depression is present in which case the condition becomes reversed, namely the muscle area protrudes outward.

The latter appearance depends upon the special development of a ledge-like thickening of the superior part of the posterior border of the ramus, first described by Lenhossek (1920) as "crista ectocondyloidea." From the condyloid process a strong beam of bone descends obliquely and terminates approximately in the middle of the surface of the ramus in a large flat swelling which may be termed "eminentia lateralis rami." It forms at the same time the superior limit of the masseteric fossa. In cases where the particular beam of the bone is more developed than normally, the fossa is substituted by a general elevation of the area in question. This means: the eminentia lateralis occupies the whole inferior part of the surface of the ramus. The crista ectocondyloidea is obviously an analogy to the anterior border of the ramus and the linea obliqua. Both these swellings have to be considered as means of transmissions of force issuing from the coronoid and condyloid processes and working in the direction toward the body. Between the crista ectocondyloidea and the coronoid process and the anterior border of the ramus respectively there is a flat depressed area. This area is delimited by the incisura semilunaris and is the thinnest part of the whole ramus.

A great variability in the formation of the lateral surface exists in anthropoids. However, the characteristic feature is that the relief is much less defined than in recent man. There also is a thickened anterior border which proceeds as an oblique line to the eminentia lateralis. The two borders forming the mandibular angle are likewise thickened and project slightly outward. But the area masseterica is seldom a real fossa, usually being flat or even elevated, and the crista ectocondyloidea is entirely absent or at best palpable as a faintly developed oblique swelling. As in recent man, the thinnest part of the ramus is framed by this swelling and the beam of the bone forming the anterior border of the coronoid process.

In *Sinanthropus* there is a distinct difference, although only slight, between the strong male mandible G I and the weaker female jaw of H I. Like the various reliefs of the body the lateral surface of the ramus reveals more structural details in the latter than in the former. In both mandibles (Plate IV, figs. 1 and 4; Plate V, fig. 1; textfig. 4; Plate VII, figs. 1, 5 and textfig. 57) the border of the region of the angle is everted like a hook;

however, the angle thus transformed to a prominent crest is thicker and more projecting in jaw G I than in jaw H I. On the other hand the anterior border in the latter (textfig. 4) continuing with the oblique line to the lateral eminence of the body (pl) represents likewise a strong ridge, so that the area of the masseter (fm) forms an appreciably deep fossa. In jaw G I the thickening of the anterior border is not so distinctly set off from the general level of the surface, the fossa being more pronounced toward the strongly everted angle and therefore forming a real deep furrow. The crista ectocondyloidea (ce) in jaw H I is a well marked ridge and a similar strong development of the eminentia lateralis rami (el) is to be seen in this jaw. The crista begins at the neck of the condyle with a small tubercle-like swelling — tuberculum subcondyloideum laterale (tl, confer p. 76). In jaw G I (textfig. 57) the crista appears to be separated into two smaller and more distinct crests (ec), an upper and a lower one. The former is closely connected with the neck of the condyle and gives the impression of being a special formation. The latter is a short and narrow rough line connected with the rather indistinct eminentia lateralis rami (el). Davidson Black (1931) determined this neck tubercle as the attachment of the temporo-mandibular ligament; viewed from the morphological standpoint it represents only the superior end of the crista ectocondyloidea.

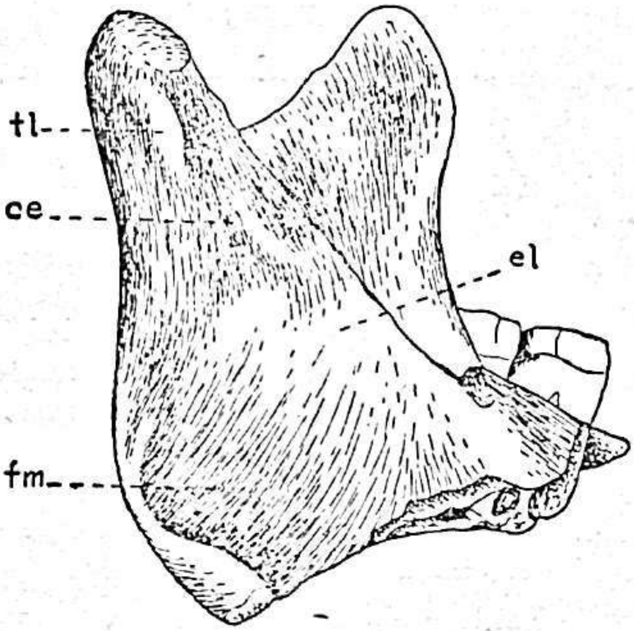


Figure 57. Lateral surface of the ramus of the mandible of male *Sinanthropus* G I. Abbreviations:— ce, crista ectondyloidea; el, eminentia lateralis rami: fm, fossa masseterica; tl, tuberculum subcondyloideum laterale. Natural size.

In all juvenile jaws in which the region in question is preserved — jaws B I (Plate II, fig. 1), C I (Plate III, fig. 1) — the eversion of the angle and the roughness of the border is already pronounced and the masseter area therefore represented by a clear fossa. In the jaws B I and F I (Plate III, fig. 5) the crista ectocondyloidea is very distinct. F I is particularly interesting, the outer neck tubercle being well differentiated and forming the superior part of the crista.

In the Heidelberg jaw the angle is everted but to a lesser degree than in the two adult *Sinanthropus* mandibles. The crista ectocondyloidea is completely absent, but the eminentia lateralis is well developed. In the Krapina jaws the angle is not turned up and the crista ectocondyloidea is only strongly developed in one ramus fragment which has no special designation. But in the Krapina jaw I there is a very pronounced outer neck tubercle like in *Sinanthropus* jaw G I. Neither in the Heidelberg mandible nor in the Krapina jaws can a real fossa masseterica be recognized. In the jaw of La Chapelle-aux-Saints the angle is turned inward. The neck tubercle is very strongly developed and the site of the crista is occupied by a large swelling which continues downward and forward. Instead of a fossa masseterica we are dealing here rather with a prominentia masseterica.

The characteristic feature of the lateral surface of *Sinanthropus* consists therefore of the marked everted angle, the existence of a real fossa masseterica and a strongly developed crista ectocondyloidea with a distinct neck tubercle below the condyle. In comparison with the anthropoids this appearance seems to be either a more advanced stage or a special differentiation. In recent man and in the Neanderthal group the variation of the relief of the ramus surface is much greater, occasionally even more in the direction of anthropoids, especially in the cases of very bulky mandibles. The eversion of the angle combined with a crest-like formation of the border proper and the deepening of the attachment area of the masseter indicate that this muscle was extraordinarily developed in *Sinanthropus*. It is worth noting that in the gorilla and orang males the area of this muscle is very extensive on account of the height and the breadth of the whole ramus, while in *Sinanthropus* the special formation of the angle compensates the relative smallness of the ramus surface. In recent man the same conditions exist. The mandibles of the Eskimo for instance are noted for their far projecting and everted angles (compare Fürst and Hansen, 1915), a phenomenon attributed by these authors to the especially strongly developed masseter in this race.

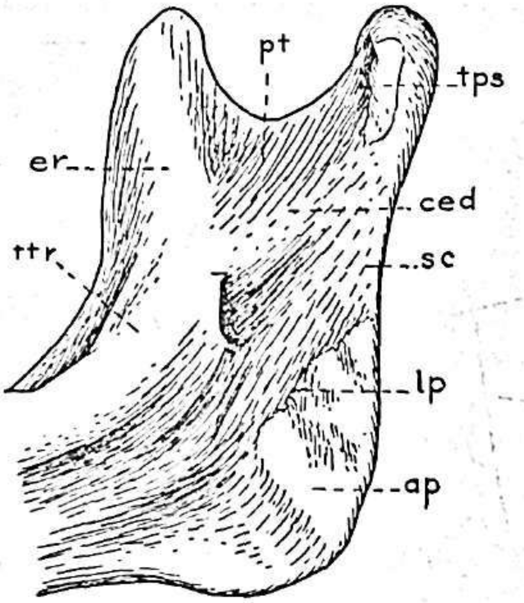


Figure 58. Medial surface of the ramus of the mandible of a modern North Chinese man (No. 17). Abbreviations:— ap, area musculi pterygoidei int.; ced, orista endocondyloidea; cer, crista endocoronoidea lp, linea pterygoidea; pt, planum triangulare; tps, tuberculum pterygoideum superius; ttr, torus triangularis; sc, sulcus colli. Natural size.

This coincidence proves that certain features occasionally found in primitive hominids are not necessarily apriori primitive characters but that they are due to variable mechanical features and therefore may be realized under the same conditions in very different stages of evolution. For the same reason it often is difficult to determine what is to be considered as "primitive" and what not. An everted and thickened mandibular angle may or may not occur in the three anthropoids mentioned above.

2. The medial surface.

The medial surface bears a special marking by showing three formations, the foramen mandibulare, a characteristic eminence before this aperture and the relief behind the foramen (between tuberositas pterygoidea and the condyle). The eminence and the adjoining area have been the subject of detailed comparative investigations by Lenhossek (1920). The eminence termed by this author as "torus mandibularis" rises from the direct continuation of the alveolar margin, which Lenhossek named "crista endoalveolaris." The crista borders on the medial side of Klaatsch's trigonum postmolare situated behind the last molar, and joins, at the end of this trigonum, the crista buccinatoria bordering the latter on its lateral side. Lenhossek's torus mandibularis (textfig. 58, ttr) continues into two ridge-like swellings. an anterior and a posterior one. The first courses along the inner side of the coronoid

Figure 59. Medial surface of the ramus of the mandible of an adult male gorilla (No. 321). Abbreviations:— ap, area musculi pterygoidei int.; ced, crista endocondyloidea; cer, crista endocoronoidea; cp, crista pharyngea; mh, linea mylohyoidea; pt, planum triangulare; tpi, tuberculum pterygoideum inferius; tps, tuberculum pertygoideum superius; ttr, torus triangularis; sc, sulcus colli. × 2/3.

process and is called "crista endocoronoidea" (cer) by the same author, and the second proceeds to the condyloid process and is termed "crista endocondyloidea" (ced). Between the two cristæ there is a flat triangular area — planum triangulare.

Lenhossek's description applies to recent man as well as to anthropoids (compare textfigs. 58-61), the general appearance being the same. In recent man Lenhossek notes in addition another formation, the crista or linea intermedia (cp) which would connect the linea mylohyoidea with his "torus mandibularis" and mark the attachment for the mylopharyngeal muscle, a part of the constrictor pharyngis superior. This crista may be strongly developed in anthropoids and could therefore represent a pithecoid character if it occurred in recent man.

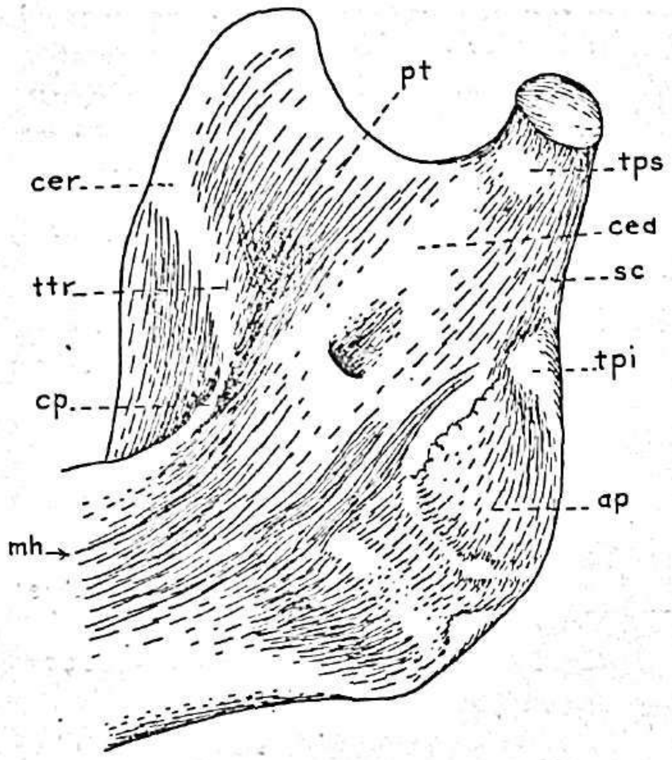


Figure 60. Medial surface of the ramus of the mandible of an adult male orang (No. 332). Designations are the same as in fig. 59. × 2/3.

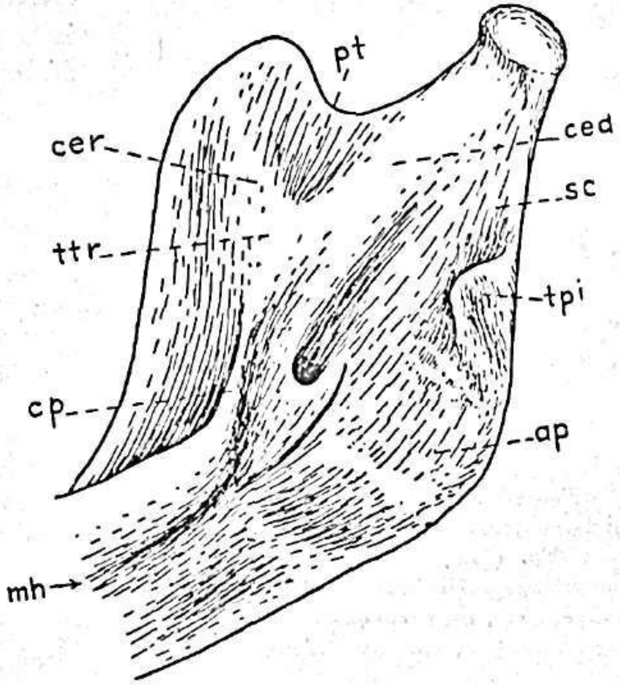


Figure 61. Medial surface of the ramus of the mandible of an adult male chimpanzee. Designations are the same as in fig. 59. Natural size.

I agree with Lenhossek in the general description but prefer to change the term "torus mandibularis" to "torus triangularis rami" (ttr) because the first mentioned name has for a considerable time been understood to define a different formation on the lingual side of the alveolar process (see above). The torus and its continuation into the two cristæ is very characteristic for chimpanzee, orang and gorilla in which they occasionally project edge-like, so that the "planum triangulare" (pt) appears as a deep and distinctly defined triangular fossa.

There is no doubt that both cristæ are to be considered as beams strengthening the bone in that direction on which the strain and force is transmitted from both processes to the body of the jaw. Thus the cristæ of the medial surface represent the counterpart of the ridge of the anterior border and the crista ectocondyloidea of the lateral surface. However. when compared with recent man a remarkable difference is to be observed. In anthropoids the crista endocondyloidea is much more marked than the crista ectocondyloidea while in recent man the reverse is usually true. Furthermore, in adult male apes the crista endo-alveolaris continuing to the torus triangularis is often changed into a sharp edge on which at some distance from the last molar a pointed spine projects inward. This edge could be termed "crista pharyngea." I was unable to determine whether it concerned a special point of fixation of the pterygomandibular raphe of the buccopharyngeal fascia or a strong portion of the M. mylopharyngeus. Generally this crista has no direct connection with the linea mylohyoidea, the latter terminating considerably below it.

Lenhossek also discussed the varying appearance of the trigonum postmolare. However. the writer is unable to observe essential differences between anthropoids and recent man in this respect.

On the right side of *Sinanthropus* jaw G I the whole region in question is well preserved (Pl. V, fig. 2 and textfig. 62). The alveolar border ends by a rather well developed edge at the torus triangularis (ttr) which continues directly into the crista endocoronoidea (cer). The crista endocondyloidea (ced) is much less marked and represents only a generally indistinct swelling. In jaw H I (textfig. 37) the division of the torus into two cristæ is slightly more pronounced but the crista endocondyloidea does not project further than in jaw G I. In the juvenile mandible F I (Plate III, fig. 6 and textfig. 64) both cristæ (crista endocoronoidea (cer) and crista endocondyloidea (ced)) are rather strongly marked and the planum triangulare (pt) is a real fossa. As much as can be judged from the material on hand, the stronger formation of this relief is a juvenile character also in recent men. In the adult male jaw G I the alveolar edge inward and backward from M_3 is also well developed on the left side (crista pharyngea, cp) and resembles more the corresponding feature in anthropoids rather than the female jaw H I. Within the Neanderthal group the jaws of Heidelberg, Spy and La Chapelle-aux-Saints reveal a close resemblance to the mandibles belonging to *Sinanthropus*.

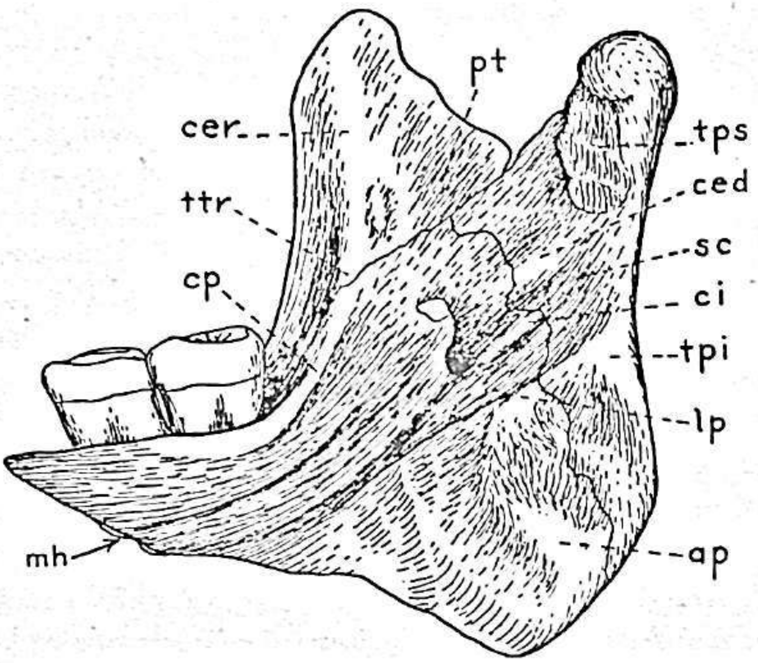


Figure 62. Medial surface of the ramus of the adult male *Sinanthropus* G I. Abbreviations:— ci, crista intermedia, lp, linea pterygoidea. The other designations are the same as in fig. 59. Natural size.

The foramen mandibulare in recent man and in the Neanderthal group differs from that of anthropoids, especially by the absence of a lingula. Also in anthropoids the anterior border of the entrance to the canal is covered by a projecting thin bone plate, but the triangular overlapping process near the upper end is completely absent in orang and chimpanzee (textfigs. 60 and 61), while it occurs occasionally in gorilla (textfig. 59). All specimens of *Sinanthropus* in which this part is preserved — G I, H I, B I, C I, F I — prove that it is like recent man in this respect. Among the Neanderthal group the jaws of Heidelberg, Spy and La Chapelle-aux-Saints reveal a close resemblance to the *Sinanthropus* mandibles.

The region between the foramen and the posterior border of the ramus is of special interest. Lenhossek described it in recent man as follows: Behind the inferior part of the crista endocondyloidea and the torus mandibularis (triangularis) there is a sulcus-like depression which leads to the foramen mandibulare. This sulcus is limited toward its posterior border by the moderately and edge-like elevated superior border of the attachment area for the m. pterygoideus internus. Sicher (quoted by Lenhossek) named this sulcus "sulcus colli mandibulæ" and Lenhossek termed it the "sulcus retrotoralis." As to the muscle area concerned this author states that it reaches the deepest place of the "incisura subcondyloidea." This incisura designates that curvature which is situated below the condyle and formed by the strong inward projection of the medial corner of the latter. However, Lenhossek does not refer to the feature of this region in anthropoids. Bluntschli (1929) gave the following description of an adult orang: Mid-way between the condyle and the angle a strong tubercle — tuberculum pterygoideum — sharply projects inward from the posterior border of the ramus. It is situated in the same level as the foramen mandibulare and corresponds according to Freisfeld (quoted after Bluntschli) to the processus angularis present in many mammals. This tuberculum is the highest and strongest of the specially developed attachment points of the m. pterygoideus internus.

Indeed, the area of this muscle has hitherto not received much attention; one was satisfied with the statement that there is a rough surface serving for the attachment of the muscle. This is certainly true but nevertheless some additional details are worth noting. Like the area of the masseter the pterygoid area generally is well demarcated from the adjoining surface (textfig. 63 ap). It consists of a triangular field the basis of which is directed upward and forward. The two other sides are formed by the mandibular angle itself. The base line of the area is represented by an obliquely coursing and rather straight line — linea pterygoidea (lp) — which occasionally also forms the posterior border of the mylohyoid groove. The inferior corner is marked by a clear swelling which constitutes the beginning of the body and the thickening of its lower margin. If the angle is turned up inward, the area gives the impression of a fossa. The base line is very variable and seldom forms (textfig. 63 lp) a distinct limit at the upper and posterior corner of the triangular area.

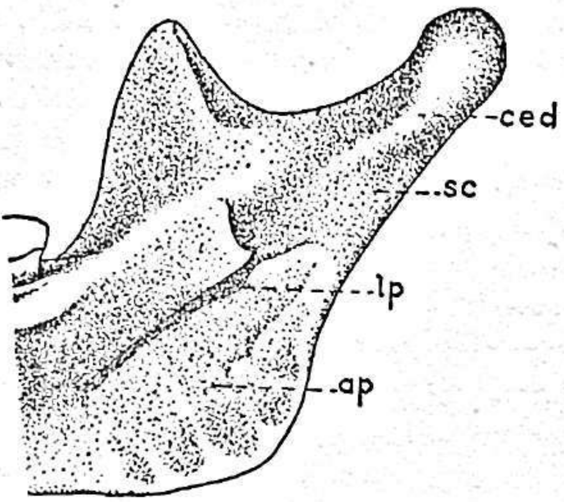


Figure 63. Medial surface of the ramus of the mandible of a New Hebrid native. Designations are the same as in fig. 59 and 62. Natural size.

Between this corner and the neck of the condyloid process there is a smooth furrow-like depression which starts from the posterior border below that process and runs to the foramen mandibulare. Its superior border is formed by the crista endocondyloidea. This crista runs out into the inferior side of the medial corner of the condyle. The site in question is frequently marked by a more or less elevated roughness (textfig. 58, tps) extending also to the deepened anterior surface of the neck, the so-called fossa pterygoidea. This rough area corresponds to the attachment for the m. pterygoideus externus so that it may be called tuberculum pterygoideum superius. The depression in question is identical with what Lenhossek described as sulcus retrotoralis and which the present writer prefers to name the "sulcus colli" (sc).

Adult and strong male gorillas exhibit all the above mentioned details with particular distinctness (textfig. 59). The area of the m. pterygoideus internus is a large triangular and deepened field (ap) which occupies the posterior part of the ramus up to the vicinity of the neck of the condyloid process. The limits are the same as those described for man. In contrast to the latter, the upper corner of the area is marked by a very strongly projecting tuberculum pterygoideum, better called tuberculum pterygoideum inferius (tpi). Opposite to this eminence and slightly below the neck of the condyle there is another strong tubercle-like prominence the site of which corresponds exactly to the tuberculum pterygoideum superius occasionally found in recent man (tps). Between these two tubercles is a deep furrow proceeding to the foramen mandibular representing the sulcus colli. It is well defined along its entire course by the strong development of the crista endocondyloidea. However, the feature here described is not at all characteristic for gorilla. Even in old male individuals the two pterygoid tubercles may be absent or only indicated. But in all cases a distinct oblique sulcus exists and the pterygoid area extends beyond the level of the foramen mandibulare.

Old orangs (textfig. 60) in general correspond to Bluntschli's description quoted above, but there exists a great variation in the degree of the formation of the two tubercles (tps, tpi). It may be that either the superior or the inferior tubercle is more developed or that both are almost missing. The superior tubercle generally consists only of a very indistinct eminence at the given site. Corresponding to this variability the sulcus colli (sc) is occasionally hardly indicated.

As to the chimpanzee (textfig. 61) the material of old individuals at my disposal is very unsatisfactory for such a study. In the case of an adult male there is an extraordinarily strong and sharply edged tuberculum pterygoideum inferius (tpi), but there is not the slightest trace of the tuberculum superius nor of any roughness in the corresponding place. In another younger specimen the tuberculum inferius exists in the same robustness. The crista endocondyloidea being well developed with the result that the sulcus colli (sc) is evident. In orang as well as in chimpanzee the area of the m. pterygoideus internus passes over the level of the foramen mandibulare.

In *Sinanthropus* the region in question is well preserved in mandible G I (right side) and in jaw H I. In the first mentioned (Plate V, fig. 2 and textfig. 62) the area of the m. pterygoideus internus is limited by a distinctly marked linea pterygoidea (lp). There are some strong ridge-like rough elevations; the uppermost of them having the form of a low tetrahedron represents the tuberculum pterygoideum inferius (tpi). Opposite to this a well developed tuberculum pterygoideum superius (tps) rises which is directed more forward than inward. Since the crista endocondyloidea projects remarkably, especially behind the lingula, the sulcus colli appears very clearly. Only one formation is unexpected, namely the presence of a short narrow crest (ci) — crista intermedia — similar to that described above on the lateral surface. This crest courses from the inferior border of the entrance to the foramen upwards and backwards and divides the sulcus into a narrower superior and a wider inferior part. Showing these details with such distinctness the male *Sinanthropus* mandible resembles remarkably the jaw of a gorilla. The female *Sinanthropus* jaw H I (Plate VII, fig. 2 and textfig. 37) being considerably weaker than the one mentioned above shows a similar feature but with much smaller tubercula, especially the inferior one. The crista intermedia is present too.

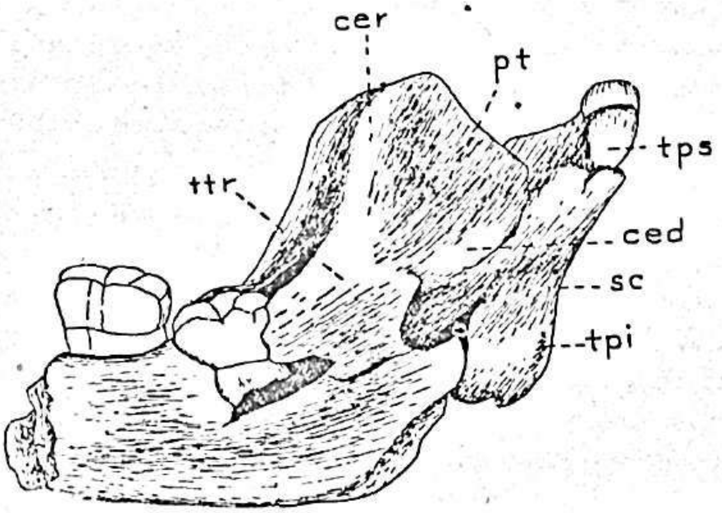


Figure 64. Medial surface of the ramus of the mandible of *Sinanthropus* male child F I. Designations are the same as in fig. 59. Natural size.

In the juvenile *Sinanthropus* jaw F I the two tubercula, a strong crista endocondyloidea and a deep sulcus are clearly recognizable (textfig. 64.) In jaw B I (Plate II, fig. 2), in which the crista endocondyloidea itself is partly broken off, all details may be observed. In jaw C I (Plate III, fig. 1) where only the upper two third of the area of the m. pterygoideus internus is intact the tuberculum pterygoideum inferius and the sulcus are well developed. However, as pointed out above, it seems that these features, with the exception of the tuberculum pharyngeum inferius, are true for all juvenile jaws including those of recent man.

In regard to the mandibles within the Neanderthal group, that of Heidelberg does not show any difference worth mentioning in comparison with recent man. Both tubercula are absent. In one of the Krapina mandibles — the ramus fragment without any special designation — the lingula continues as a fine edge almost to the posterior border of the ramus; a projecting tuberculum pterygoideum inferius exists in jaw I of that group. The jaw of the Ehringsdorf child is characterized by a very strong and projecting tuberculum pterygoideum inferius, noted by Virchow (1920). The condyloid process is partly broken off, but the preserved sharp corner at the line of fracture suggests that a tuberculum pterygoideum superius was also existing.

The mylohoid groove deserves special mention. In recent man it usually descends directly from the inferior part of the thin bone plate which covers the entrance to the mandibular foramen. Occasionally this starting point is shifted backward, that is to say, the groove descends from behind that entrance. This feature is characteristic for anthropoids as was proven by Friederichs (1932). Incidentally, it is also found in the Piltdown jaw. *Sinanthropus* in this respect is like recent man; in both cases (G I and H I, textfigs. 62 and 37) the groove is wide in the beginning, but in jaw H I there are besides it several extraordinary fine grooves like engravings in the bone, one of them being visible as far as up to the level of P_2.

In spite of the great variability the areas for the attachment of the two m. pterygoidei in *Sinanthropus* reveal a very characteristic feature remarkable for the strong development of the muscle markings which are still more pronounced in the male individual G I than in the female jaw H I. Compared with the Heidelberg jaw noted especially for the largeness of its ramus the area of the m. pterygoideus internus is not only relatively but also absolutely broader than that of the former. The height of this triangular area of the muscle is 26.4 mm in the Heidelberg jaw and 28.2 mm in *Sinanthropus* G I. The diameter of the whole ramus measured in the same oblique direction (linea obliqua — gonion) is 50.7 mm in the Heidelberg jaw and 49.0 mm in *Sinanthropus* G I. The respective indices are 52.0 in the former and 57.6 in the latter. If we accept the general opinion that strong muscle markings are indicative of powerful musculature, then we must conlude that in *Sinanthropus* the pterygoidei have been very powerful and certainly more so than in recent man and in the Neanderthal group. The same is true for the masseter. This fact seems to be of some value, because Boule deduced a prevalence of the pterygoideus internus in the jaw of La Chapelle-aux-Saints from differences in the development of the muscle markings of this muscle in comparison with that of the masseter and concluded therefrom that the man of La Chapelle-aux-Saints was a vegetarian. I am somewhat in doubt on the correctness of such conclusions, yet the fact that *Sinanthropus* was a skillful hunter as shown by the innumerable broken bones of many varieties of game proves that he did not use his masticatory muscles on vegetables only.

Freisfeld considered the tuberculum pterygoideum inferius in connection with the processus angularis; however, the present writer does not believe that it is possible to consider the two directly homologous. The tuberculum concerned represents nothing else but an especially strongly developed muscular marking of the pterygoid area and similar to the others is situated exclusively on the inner side of the ramus, while the processus angularis is a proper process directed posteriorly existent in prosimians and already completely absent in lower monkeys.

3. Mandibular angle — processus coronoideus and condyloideus.

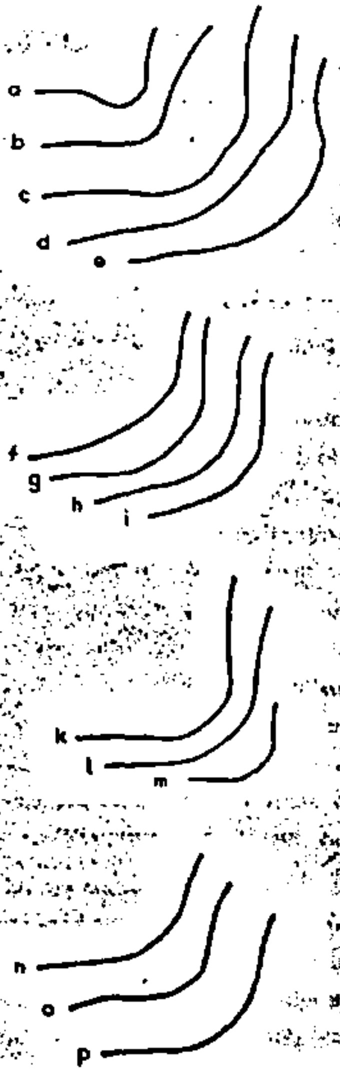
In this paragraph parts of the ramus belonging to both sides will be described. Some of the peculiarities have already been discussed earlier in this publication.

Mandibular angle: Under the term "mandibular angle" is understood not only the angle formed by the posterior border and the lower margin of the ramus but also the morphological feature of this point of union. The degree of the angle which manifests the steepness of the ramus will be discussed below in connection with the questions regarding the general appearance of the mandibles. Here we shall deal with the shape of the angle.

In recent man this angle is generally represented by a more or less regularly curved projection directed outward, backward and downward and therefore separated by slight but distinct notches from the anterior part of the lower margin and the superior part of the posterior border (textfig. 65 a). The first notch is called "incisura praeangularis," the second "incisura supraangularis" (confer H. E. Schulz, 1933, and Keiter, 1935). Keiter differentiates six different forms in the angular projection. However, we are only concerned with his first form known as the sledge-runners ("Schlittenkufen") form and characterized by an equal curvature and by the absence of any kind of projection and notch. For more detailed information on the comparative anatomical significance of this projection the reader is referred to Toldt (1904/05). Keiter's form No. I is illustrated in textfig. 65 m. However, although cases with such a form are not frequent, in most of them the curvature just at its highest point is bevelled to form a blunt line.

Such a bluntness which occurs rather frequently in the mandibles belonging to the Neanderthal group (textfig. 65, i) induced Werth (1928) to suppose that we are dealing with a progressive character the occurrence of which would indicate that the Neanderthal group is highly specialized and more advanced in this respect than recent man with his usually projecting mandibular angle. Boule (1911/13) in describing this peculiarity, especially in the mandible of the man of La Chapelle-aux-Saints (textfig. 65, f), and in pointing out its frequent occurrence in the gorilla (textfig. 65, d) considered it only as an additional indication of the powerful development of the m. pterygoideus internus (see above). In the Ehringsdorf jaw H. Virchow (1920) considered the approach of the outline of the angle to a straight line as anthropoid-like.

In connection with Werth's supposition it should be noted that the formation of the angle as well as that of the blunt form varies to a large extent. The two Krapina jaws (textfig. 65 h, i) and that of Heidelberg (textfig. 65 g) show only a slight bluntness while the curvature is clearly projecting. Toldt's (1904/05) investigations have proven that no direct relation exists between the processus angularis of the prosimians and the mandibular projection of recent man. On the other hand the gibbon and the chimpanzee exhibit very strongly projecting angles (textfig. 65 a, b) and the same is true for the orang where occasionally a slight bluntness similar to that of the Heidelberg jaw is to be observed (compare textfig. 65, c and g). In the gorilla the angle does not infrequently also project as is demonstrated by textfigure 65, e. H. E. Schulz (1933) has proven that the process is absent in 50% of Negro and Old-Egyptian jaws.



Heidelberg

Figure 65. Differences in the angle contours of the ramus. Designations:— a, *Symphalangus syndact.* ♂; b, chimpanzee ♂; c, orang ♂; d, gorilla ♂; e, gorilla ♀; f, La Chapelle-aux-Saints; g, Heidelberg; h, Krapina (without designation); i, Krapina I; k, *Sinanthropus* G I; l, *Sinanthropus* H I; m, *Sinanthropus* child C I; n, Prehistoric Chinese (Kansu); o, modern Australian native; p, Obercassel. × 1/2.

In *Sinanthropus* jaw G I the angle of the ramus of the right side is preserved up to its transition into the lower margin (Plate VII, figs. 1, 2 and textfig. 65, k). However, the left side preserved to about this point reveals that a well developed incisura præangularis had existed (Plate IV, figs. 1, 2). Therefore it can be considered to be certain that in the *Sinanthropus* jaw the angle projected to the degree as found in recent man. But there is a distinct, although only faint, bluntness of the summit of the angle. In *Sinanthropus* jaw H I in which the whole angle is preserved the bluntness is more pronounced (Plate VII, figs. 1, 2 and textfig. 65, l). Of particular interest is the juvenile *Sinanthropus* jaw C I in which the angle is clearly projecting out at the same time blunt (Plate III, figs. 1, 2 and textfig. 65 m). In *Sinanthropus* the bluntness is combined with a *strong* eversion of the angle. The jaw belonging to the Obercassel man which bears a striking resemblance to the *Sinanthropus* jaw G I in this respect shows the same eversion and bluntness (textfig. 65, p). A glance at the illustrations of the Eskimo mandibles reproduced by Fürst and Hansen (1915) shows that the same combination is rather frequent there. In La Chapelle-aux-Saints the bluntness is combined with an inversion of the angle. In gorilla the present writer observed the occurrence of the bluntness combined with eversion and inversion.

From all these facts the writer assumes that none of the various types of mandibular angles have a special phylogenetic significance. A projecting angle with a slight bluntness of its summit seems to be characteristic for hominids in all stages of evolution. Yet as a great variability is already to be observed in anthropoids, the sledgerunners' shape evident in recent man as well as within the Neanderthal group is not at variance with this statement. In any case there is no evidence that the latter shape really represents a special differentiation deviating from the main line of human evolution.

The coronoid process: The shape of the coronoid process varies considerably in recent man. As to the form of the outline H. E. Schulz (1933) established six various types the most frequent of which is illustrated in textfigure 66, l-n. The illustrations show that there are great differences in height and breadth, in the form of the top and in the position of the latter with regard to the direction of the anterior border. According to Biondi (1890) the coronoid process of lower races would be less high, less broad and less strong than of Whites, but he calls attention also to the great variability.

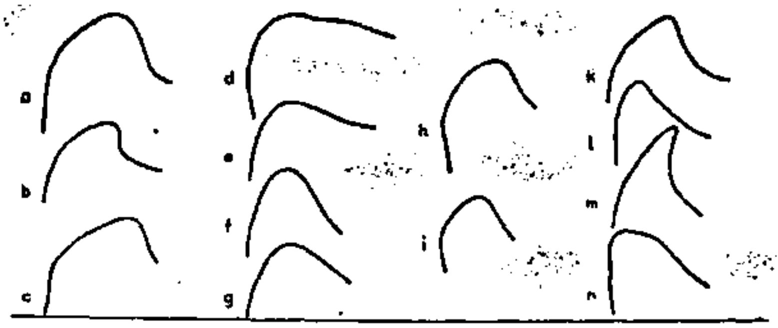


Figure 66. Outlines of the coronoid process oriented in the alveolar plane. Designations:— a, gorilla ♀; b, orang ♀; c, chimpanzee ♂; d, Heidelberg; e, modern Eskimo; f, Krapina I; g, Ehringsdorf child; h, *Sinanthropus* G I; i, *Sinanthropus* H. I; k-n, four types of modern man according to the diagrams given by Schulz (1933, Nos. 1, 2, 4, 5). × 1/2.

In anthropoids the differences within a single genus are certainly not so great. Gorilla (textfig. 66 a) has the highest process, those of orang and chimpanzee (66 b, c) are lower and relatively broader. The only feature characterizing all three is the tendency to incline backward. In that case the top is not a direct continuation of the anterior border but the latter forms a slight angle. The result is the appearance of a special superior border the end of which represents the top (a-c).

In recent man such an angle is absent, the anterior border ascending directly to the top (n) or coursing in a more or less posteriorly directed curved line (k, l, m). In the jaws of the Neanderthal group the top is directed straight upward (f, g) — of course, it is understood that only specimens with completely preserved processes can be used for such a comparison. The Heidelberg jaw has a type of its own in that its coronoid process is so low that it scarcely ever rises from beyond the outline of the mandibular notch (d), but the top is directed upwards and comes to lie just at the end of the anterior border. This feature is unusual in anthropoids and monkeys and can therefore never be considered a primitive characteristic. It is also unusual for the Neanderthal group as a whole and the same is true for recent man. However, this does not imply that such a feature is never found. In the Senckenberg-Museum in Frankfurt there is a jaw of a male Eskimo with exactly the same shape of the process (e). The latter approaches the Heidelberg jaw in its extraordinary breadth of the ramus:

	Heidelberg	Eskimo
Length-breadth-index	75.4	63

Among the Eskimo skulls described and illustrated by Fürst and Hansen (1915) there are several jaws with very low processes and very broad rami closely resembling the Heidelberg jaw, especially skull No. 331 (see below). Fürst and Hansen state the ramus index of the latter as being 70.3 which is not much less than that of the Heidelberg jaw. Therefore it is evident that the particular feature of the coronoid process of the Heidelberg jaw is in direct correlation with its extraordinary breadth. However, the two phenomena are not at all primitive but merely represent an individual or some other special variation.

That the statement just made is correct is proven by the coronoid process of the *Sinanthropus* mandibles. In jaws G I and H I one coronoid process of each specimen is completely preserved (Plate V, figs. 1, 2, Plate VII, figs. 1, 2 and textfig. 66, h, i). Apart from a slight variability, especially in size, the general appearance is the same. A comparison of the coronoid process in the *Sinanthropus* jaws with that of the anthropoids on one hand, and the Neanderthal group and recent man on the other, reveals very distinctly that *Sinanthropus* in this respect approaches more the anthropoids than the other two groups. *Sinanthropus* jaws show the same tendency of forming an angle and a superior border.

With reference to other details of the coronoid process the only one worth mentioning is its triangular form in cross section which means that the process is flat on the lateral side but shows a distinct ridge on the medial side, that is, the crista endocoronoidea ascending to the top. Combined herewith is a thickening of the anterior border, the two features together giving the process a strong and robust appearance. *Sinanthropus* resembles in this respect more the chimpanzee than the gorilla or orang because the latter have flat and slender processes. Such a strong triangular process like that of *Sinanthropus* is observed very seldom, even in the most robust mandibles belonging to recent man.

The condyloid process: The most striking feature of the condyloid process in *Sinanthropus* is its relative slenderness in comparison with the jaws of La Chapelle-aux-Saints and Krapina I. The completely preserved right condyle of *Sinanthropus* jaw (Plate V, figs. 1-5) makes it possible to obtain reliable measurements.

The greatest length of the condyle is 23.2 mm, the greatest breadth 10.4 mm, the corresponding figures for the restored right condyle of *Sinanthropus* jaw H I (Plate VII, figs. 1-3; Plate X-XIII, fig. 2) being 18.2 mm and 10.3 mm respectively. The following table shows the length-breadth index computed from figures obtained by the writer and other investigators:

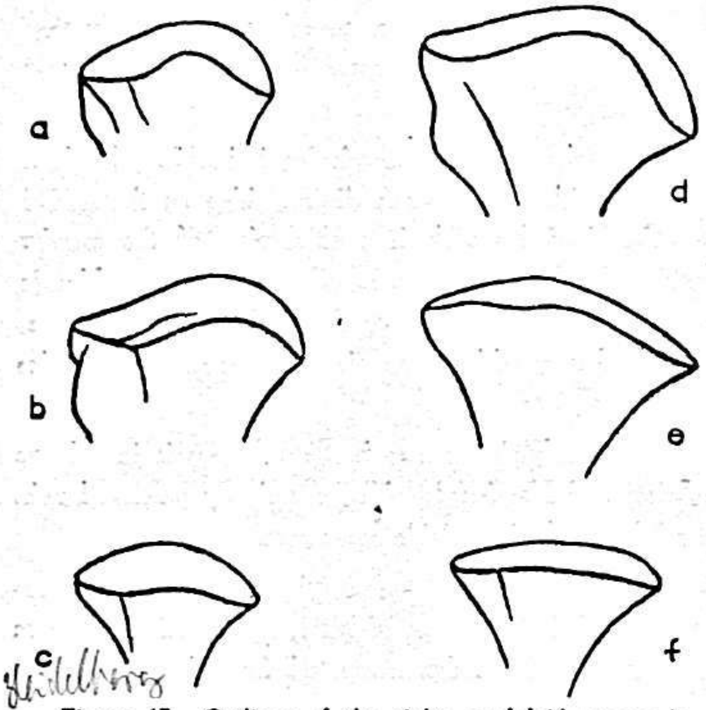
TABLE V.

Length-breadth index of the condyle.

Gorilla (average)	47.1	
Orang ,,	55.0	(42—65)
Chimpanzee ,,	45.0	
Sinanthropus G I	44.8	
Sinanthropus H I	57.2	
Heidelberg	64.2	
Krapina I	54.0	
La Chapelle-aux-Saints	46.5	
European (average)	41.4	(Sarasin)
Melanesian ,,	45.3	(Keiter)
Australian ,,	45.7	(Keiter)

These figures show the relation between length and breadth varying within a wide range. Compared with orang the index of the *Sinanthropus* jaw G I on one side (44.8) and that of the Heidelberg jaw on the other (64.2) does not exceed the limit valid for one species, that is to say, that thick and thin condyles may occur in all. With reference to this factor we are dealing with an individual variation without any phylogenetic significance.

The variation in thickness means that the shape of the condyle represented by a sagittal section varies between thick and thin cylinders in anthropoids as well as in hominids. This fact is somewhat surprising because the corresponding mandibular fossa of the temporal bone shows great differences between apes and man. The fossa is smooth or slightly shallow in the first, but deepened to a more or less narrow pit in the latter. In the two temporal bones of *Sinanthropus* Skull I Locus E and Skull III Locus H (compare Weidenreich, 1935) — the mandibular fossa is rather narrow. As the attainment of the congruity between fossa and condyle turns out to be a matter of the articular disc, it becomes evident that the shape of the condyle does not permit a hypothesis on the shape of the fossa and the reverse.



X Heidelberg

Figure 67. Outlines of the right condyloid process in frontal view. Designations:— a, *Sinanthropus* G I; b, La Chapelle-aux-Saints; c, Heidelberg; d, gorilla ♂; e, orang ♂; f, chimpanzee ♂. Natural size.

As to the shape of the articular surface of the condyle of *Sinanthropus* G I its outline in transversal section gradually rises to a dome-like swelling and then slopes steeply inward (textfig. 67 a). The inferior margin of the surface comes to lie in a much lower level on the inside than on the outside. The same feature occurs, though seldom, in recent man where the surface usually is flatter and curved in the same way as in *Sinanthropus* jaw H I. The condyle of the mandible of La Chapelle-aux-Saints (67 b) resembles that of *Sinanthropus* G I in this respect; Boule had already called attention to the formation in 1911/13. In the mandible of Heidelberg (67 c) the surface is higher as a whole but curved in the same way. In this connection it should be noted that the feature of the *Sinanthropus* G I and La Chapelle-aux-Saints condyle is very common in gorilla (67 d), especially the steep slope on the inner side, whereas in orang (67 e) and chimpanzee (67 f) the flat form prevails. Nevertheless, the shape of the articular surface is not more characteristic for a special stage of evolution than the shape of the whole condyle.

In the sections dealing with the outer and inner surfaces of the ramus the writer already called attention to the tubercles found on both sides of the neck of the condyle. There it was shown that the "tuberculum subcondyloideum laterale" appears only to represent the uppermost part of the crista ectocondyloidea. In *Sinanthropus* jaw G I this tubercle (textfig. 57, tl) is an oval, smooth projection of about 10 mm length and 3.5 mm thickness separated from the articular surface by a distinct paraglenoid sulcus. The jaw of *Sinanthropus* H I (textfig. 4, tl) is damaged at this point, nevertheless it can be seen that the tubercle had been present. The tuberculum laterale is not confined to *Sinanthropus*. Boule (1911/13) described its occurrence in the jaw of La Chapelle-aux-Saints and called it "apophyse hypocondylienne." Gorjanovic-Kramberger found the same formation in the Krapina jaws. In Krapina jaw I it is indeed very pronounced. This tubercle is not infrequent in recent man, having been found to be quite well developed in two Australian jaws and also in some of our Chinese skeletal material. As stated above, the tubercle is very characteristic for strong gorilla jaws; in male orangs a more or less prominent roughness may be found on this side, but a tubercle is completely absent in chimpanzee as far as I am able to ascertain.

The corresponding tubercle on the medial side of the condyle, the tuberculum pterygoideum superius, has been described in detail earlier in this publication in connection with the region of the foramen mandibulare. Here again the writer can only repeat that this tubercle has a greater comparative value than the other one on the lateral side, although it is not completely absent in recent man. In the latter it is represented at best as a rough spot on the medial part of the fossa pterygoidea.

Both tubercles obviously bear the character of strong muscular markings which is in conformity with the entire appearance of the *Sinanthropus* jaws, especially with that of jaw G I, thus serving only in such an indirect way as primitive features.

Gorjanovic-Kramberger (1909) as well as Boule (1911/13) considered the strong projection of the condyle toward the lateral side in the jaws of Krapina and La Chapelle-aux-Saints respectively a primitive feature. Virchow (1920) stated to have observed this feature only once in recent man. It is true that the condyle projects considerably lateralward in the mandibles of La Chapelle-aux-Saints, Malarnaud and Le Moustier. However, this is not the case in the Heidelberg jaw, nor does it hold good for *Sinanthropus*. Disregarding the tuberculum subcondyloideum laterale in *Sinanthropus* jaws G I (Plate V, fig. 3, textfig. 67 a), H I (Plate VII, figs. 3, 5) and F I (Plate III, fig. 7) the superior border of the ramus limiting the mandibular notch meets the anterior side of the condyle near its lateral corner. Only the condyle fragment of *Sinanthropus* jaw B II shows the same feature as the Neanderthal mandibles mentioned above. On the other hand, it is important that among the anthropoids the condyle projects lateralward only occasionally in the gorilla, while in orang and chimpanzee the conditions are the same as in *Sinanthropus* and recent man. Therefore the feature in question has no comparative value.

The same is true for the direction of the long axis of the condyle. In the jaws of the Neanderthal group including that of Heidelberg, this axis forms a distinct obtuse angle opening medianward to the superior border of the ramus. In recent man this angle varies from a right to a slightly obtuse one. In *Sinanthropus* G I the angle is slightly acute, in H I slightly obtuse and in F I more obtuse. In gorilla and orang this variability occurs to the same extent.

The respective height of the processes: In both adult *Sinanthropus* jaws G I and H I the coronoid process is higher than the condyloid one. The difference is slightly greater in H I than in G I. In recent man both possibilities are realized. In our collection of Chinese jaws occasionally the condyloid process will be found to be higher than the coronoid process and at other times the reverse will be observed. The differences may be quite considerable. In anthropoids the coronoid process usually is higher but it may be found that both processes are equal; in gorilla the condyloid process occasionally exceeds the coronoid. What the original conditions may have been is difficult to determine.

V. THE GENERAL APPEARANCE OF SINANTHROPUS MANDIBLES DEFINABLE BY MEASURING METHODS

In this chapter I shall discuss the general appearance of the *Sinanthropus* mandibles as far as it can be defined by measurements. R. Martin's textbook (1928) enumerates a great number of such measurements, but many of them are without comparative value, at least in the way in which they are recommended to be taken. In a very recent publication just received after the completion of this manuscript, Morant, Collett and Adyanthaya (1936) discuss the best methods for obtaining reliable measurements on the mandible. As I will show below, the length measurements pertaining to the chin as foremost landmark for comparative purposes cannot be applied to such cases in which the chin is absent. Apart from this, I prefer to take most of the measurements on orthogenic projections obtained with the aid of the stereograph by Schwarz, this method undoubtedly yields the most certain results.

Below the measurements are classified into four groups according to their relation to the parts of the mandible as follows: measurements of the body, measurements of the ramus, measurements of the whole mandible and measurements of the three mandibular arches.

A. MEASUREMENTS OF THE BODY.

1. Angle of inclination of the frontal part. The angle which the frontal part forms within a horizontal plane permits a judgement of the degree of prognathism. Usually it is measured by tracing a parallel to the Frankfort plane starting from the incision and a tangent starting from the same point and touching the most salient point of the chin (pogonion). The so-formed angle known as the "chin angle" (angle symphysien) can only be taken if the Frankfort plane is known, that is to say, if the whole skull is preserved. If the mandible alone is preserved, the chin angle may be measured by tracing the same tangent and the line or plane of the lower margin of the jaw (basal tangent). Since it is difficult to determine the latter plane correctly, preference is given to the alveolar plane or alveolar line (Klaatsch, Virchow). This line is traced from the incision to the most salient point of the alveolar border between the second and third molars. It is independent from the occasionally irregular and undulated curve of the lower margin. On the other hand, the tangent joining the incision to the pogonion is also unsatisfactory on account of the great variability of the latter point which does not indicate the degree of the actual inclination of the frontal part but only the accidental and subordinate prominence of the tuber symphyseos. Therefore to determine the "chin angle" the writer chose the alveolar line on one hand (al) and the incision-gnathion-line (i-gn) on the other (textfig. 68). Both lines can be traced quite accurately on the craniogram, while the contours were derived by the use of Schwarz's stereograph. The "chin angle" obtained by this method is of course different from those obtained by other means. Textfigure 68 shows the outlines of the profiles of the adult *Sinanthropus* jaws G I (68 a) and H I (68 b) and those of the cross sections through the symphysis in their correct position to the alveolar plane. The angle between this sagittal mid-line and that connecting the incision with the gnathion represents the real chin angle or better the angle of inclination of the frontal part. Textfigures 69 and 70 illustrate the same for the juvenile *Sinanthropus* jaws B IV and B I as also a comparison between *Sinanthropus*, chimpanzee, Neanderthal and recent man of the same ages.

This angle is very acute in anthropoids and lower monkeys, it approaches the right angle in *Sinanthropus* and the Neanderthal group and it does so still more in recent man where it occasionally becomes obtuse. Such a change implies that the frontal part becomes gradually erected according to the transition from prognathism to orthognathism. In textfigures 71 and 72 there are grouped some characteristic angles and cross sections of the symphysis of typical representatives of the primates just quoted. Table VI elucidates this feature with the corresponding figures which are arranged according to the size of the angle.

The drawings and figures show that prognathism and development of the chin (mentum osseum) are two different phenomena. It is well known that also in recent man the latter may exist in spite of a high degree of prognathism (textfig. 71 r, s). Such cases represent the so-called "negative chin" (Klaatsch). As discussed above, the projection of the basal part (mentum osseum) is chiefly a consequence of a reduction of the alveolar process due to a reduction of the roots of teeth. This reduction becomes evident by the inward curve of the outlines (textfigs. 71 and 72) indicating the incurvatio mandibulae anterior. It begins to become manifest in the Neanderthal group and is a characteristic of recent man.

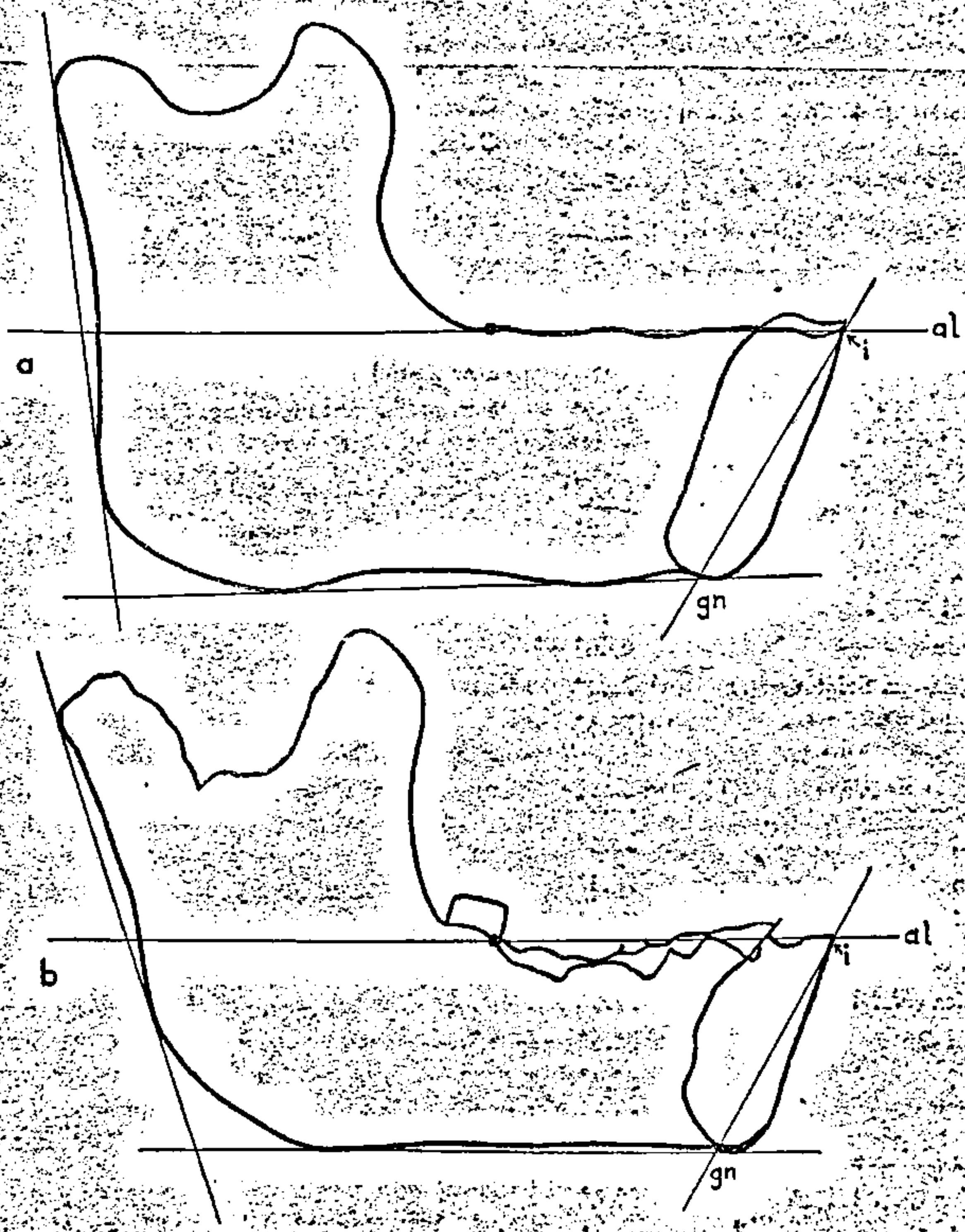


Figure 68. Diagrams of *Sinanthropus* mandibles G I (a) and H I (b) in profile views, with the median sections through the symphysis indicated in correct orientation and projection to the alveolar plane. The lines of orientation are represented by fine lines. Abbreviations:— al, alveolar line; i-gn, incision-gnathion line. Natural size.

TABLE VI

Angle of inclination*

a. Adult		b. Juvenile	
Baboon	40°	Chimpanzee child (milk teeth)	54.0°
Chimpanzee	44-49°	Chimpanzee child (permanent incisors)	51.0°
Gorilla	47-49°		
Orang	50-54°	*Sinanthropus* B IV (milk teeth)	63.0°
Symphalangus syndact.	49-60°	*Sinanthropus* B I (permanent incisors)	63.5°
Semnopithecines	52-57°	*Sinanthropus* B V (canines erupting)	59.5°
Sinanthropus G I (rest.)	59°	Gibraltar child (milk teeth)	75.5°
Sinanthropus H I	60.5°	Ehringsdorf child (permanent incisors)	65.0°
Heidelberg	60.5°	Chinese child (milk teeth)	75.0°
Krapina G	62.5°	Chinese child (permanent incisors)	86.0°
Krapina I	63.5°		
Krapina H	63.5°		
La Naulette	65.0°		
La Chapelle-aux-Saints (rest.)	70.0°		
Malarnaud	70.5°		
Chinese No. 69♂	73.0°		
Wadjak II	73.5°		
Australian	74.5°		
Spy I	77.0°		
Predmost ♂	77.0°		
Choukoutien (No. 104) ♀**	77.0°		
Obercassel ♀	78.5°		
Predmost ♀	82.0°		
Eskimo	88.0°		
Prehistoric Chinese	88.0°		
Choukoutien (No. 101) ♂	91.0°		
Obercassel ♂	94.0°		

* Some of the figures slightly disagree with those given by me in my earlier publication (1934). The reason for such discrepancy is the revised method of determining the alveolar plane.

** The specimens listed here as Choukoutien represent material belonging to recent palæolithic man recovered from the so-called "Upper Cave" of Choukoutien and which was briefly described by the late Davidson Black in a preliminary announcement (1934a).

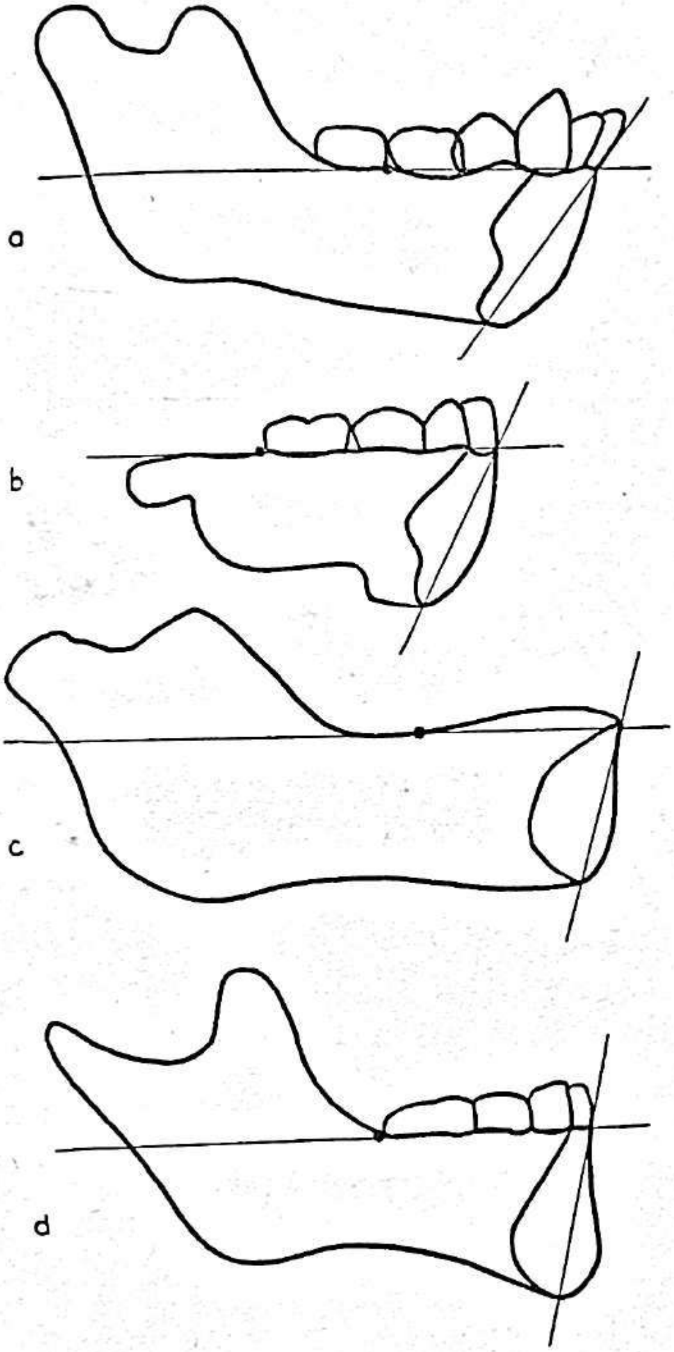


Figure 69. Diagrams in profile views representing mandibles with the milk teeth oriented in the alveolar plane. Designations:— a, chimpanzee child (No. 381); b, *Sinanthropus* child B IV; c, Gibraltar child; d, modern North Chinese child. Natural size.

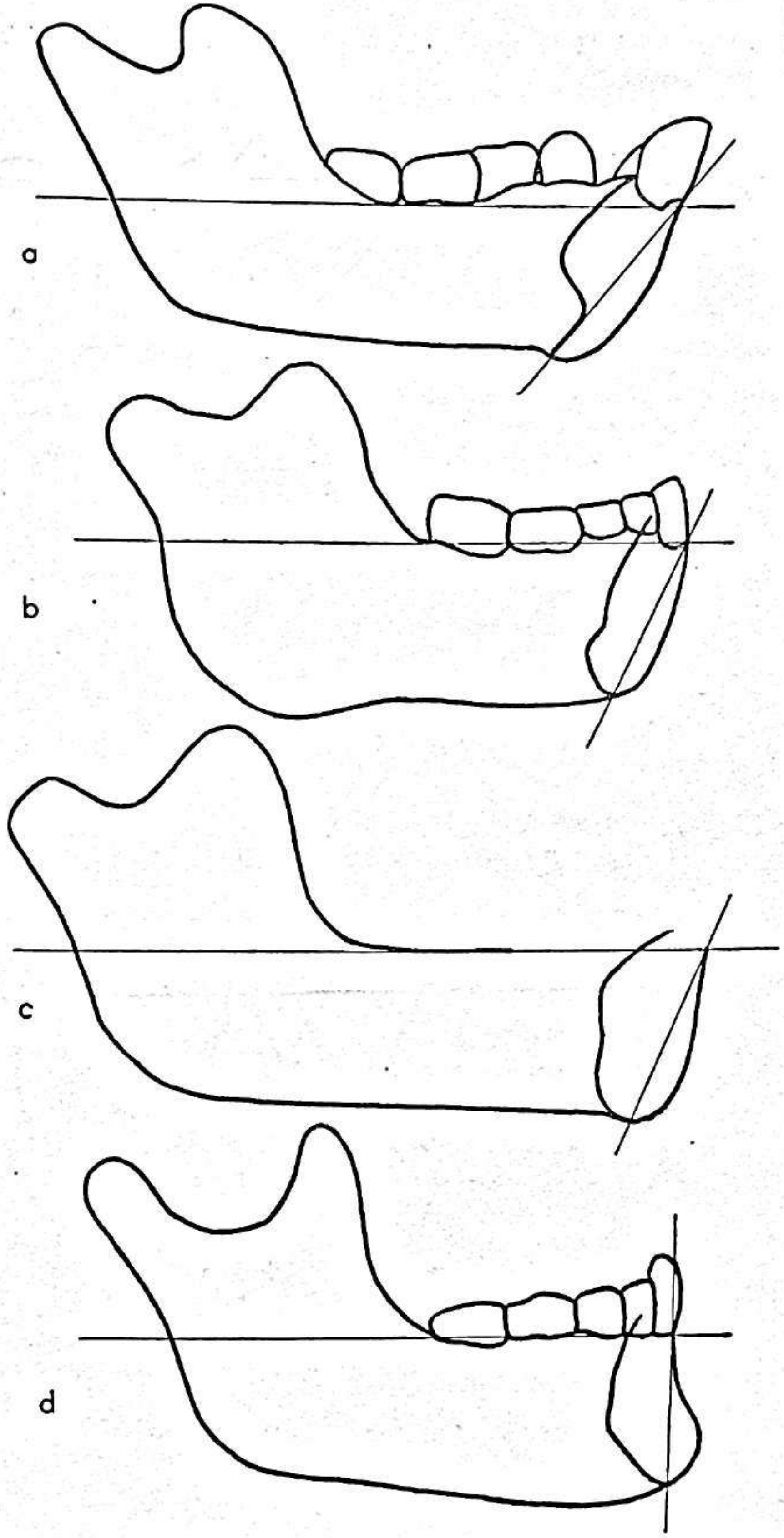


Figure 70. The same as in fig. 69. Juvenile mandibles of the later stage of dentition (with permanent incisors). Designations:— a, chimpanzee child (No. 321) b, *Sinanthropus* child B I; c, Ehringsdorf child; e, modern North Chinese child (No. 44). Natural size.

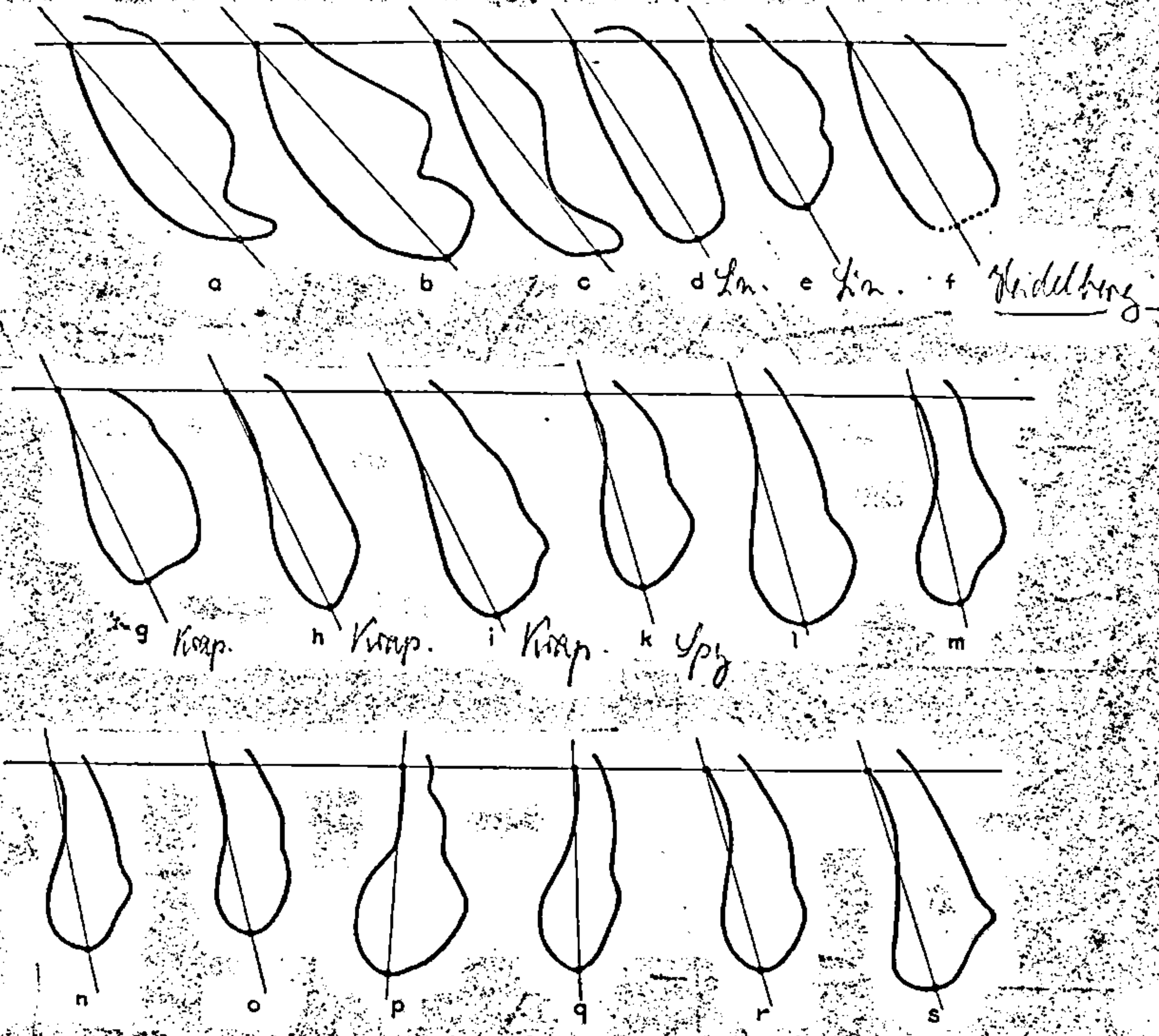


Figure 71. Median sections through the symphysis of adult individuals oriented in the alveolar plane. The incision-gnathion line indicates the angle of inclination. Designations: a, chimpanzee ♂; b, gorilla ♀; c, orang ♀; d, *Sinanthropus* G I; e, *Sinanthropus* H I; f, Heidelberg; g, Krapina G; h, Krapina I; i, Krapina H; k, Spy I; l, Wadjak II; m, Predmost ♂; n, Obercassel ♀; o, Choukoutien ♀ (104); p, Obercassel ♂; q, Prehistoric Chinese (Kansu); r, modern Australian native (No. 14); s, modern North Chinese ♂ (No. 69). Natural size.

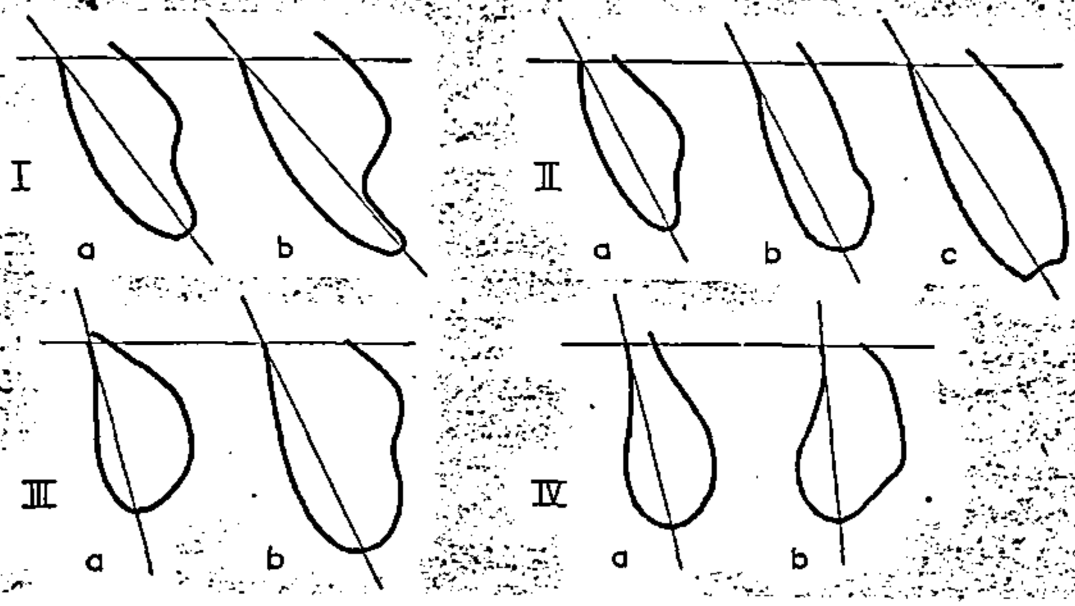


Figure 72. Median sections through the symphysis of juvenile individuals oriented in the alveolar plane. Designations:—I a, chimpanzee child with milk teeth; b, chimpanzee child with permanent incisors. II a, *Sinanthropus* child B IV with milk teeth; b, *Sinanthropus* child B I with permanent incisors; c, *Sinanthropus* child B V with erupting permanent canines. III a, Gibraltar child with milk teeth; b, Ehringsdorf child with erupting permanent canines. IV a, modern North Chinese child with milk teeth; b, modern North Chinese child with permanent incisors. Natural size.

As further demonstrated by the drawings the angle of inclination grants no measure for the variable height of the prominence of the chin. If it should be considered of importance to know the exact measure, it could be calculated by determining the curve rates of the anterior outline coursing between incision and gnathion. Failing to understand the comparative value of figures thus derived, I omitted to make such calculations.

As the method I applied for determining the angle of inclination is different from that of other authors, a direct comparison of the figures concerned is not possible. For this reason the figures for this angle which were obtained by applying the usual methods are also included. The angle formed by the incision-gnathion-line and the basal margin of the mandible (No. 79 Ia according to R. Martin's list) taken on the craniogram is 123° in the reconstructed *Sinanthropus* jaw G I (textfig. 68 a), 114° in the original jaw H I (textfig. 68 b) and 123° in the original juvenile jaw B I (textfig. 70 b). The angle formed by the basal margin and the anterior outline of the symphysis ("line symphysienne" of the French authors) amounts to 116° for the first and 109° for the latter mentioned. However, the inaccuracy in tracing that outline when it is more or less convex should be taken into account, such as in the case of *Sinanthropus* jaw G I. In the *Sinanthropus* jaw B I this measurement cannot be taken on account of the convexity of that line. R. Martin (1928) as well as Boule (1911/13) give a table of figures, but those of Martin certainly do not correspond to the method of measurement which he declared as representing the standard. Boule's figures referring to the Neanderthal group are as follows:

Spy	111° or 105-106°
Malarnaud	110°
La Chapelle-aux-Saints	104°
Krapina G and H	99°
La Naulette	94°
La Ferrassie	85°

The figures for Spy in this list are certainly too high. On the cast of the latter the writer found the angle ranging from 85° to 99° according to what was considered as the line of the lower margin or symphyseal line. In any case all these figures prove very clearly that the angle of inclination in *Sinanthropus* is much higher than within the Neanderthal group, including the Heidelberg jaw, and that it approaches the chimpanzee and orang closely in which the angle of inclination amounts to 115° and 124° respectively according to Boule's observations.

A comparison of textfigures 69, 70 and 72 and Table VI b with textfigures 68, 71 and 73 and Table VI a reveals that the angle of inclination in chimpanzee, *Sinanthropus* and Neanderthal man is higher in childhood, that is to say, as long as the permanent dentition is not completed, than in the adult stages. However, the figures in Table VI offer no security for considering this phenomenon as a general rule because the angle varies not inconsiderably and because the stages of ontogenetic development, on which these statements are based, belong to different individuals, possibly with different angles. Nevertheless, the drawings and the figures prove that in all four groups — anthropoids, *Sinanthropus*, Neanderthal man, recent man — a common "mesogeneiotic" mandible which Bolk (1926) considered the earliest stage of ontogenetic development in primates had never existed. In chimpanzee the inclination is less in juvenile jaws, becoming more intense with the second dentition. The same is true for *Sinanthropus* although the change here is not quite so marked as in the chimpanzee. In recent man the reverse process generally takes place as shown in my publication on the origin of the chin (1934) to which the reader is referred. It is of interest to note that in this respect *Sinanthropus* seems to follow more to the rule that is characteristic for the chimpanzee than that for recent man. Notwithstanding this fact, in the publication just mentioned I described the degree of the angle of inclination in gorilla and orang as being higher in the adult stage than in the juvenile. At that time I believed that the result of this finding was accidental on account of the specific chimpanzee material at my disposal. However, I have observed the same phenomenon in the chimpanzee material belonging to the collection of the Cenozoic Research Laboratory. Thus the difference noted between orang and gorilla on the one side and chimpanzee on the other is not accidental but an actual fact, which deserves consideration in regard to the conformity to *Sinanthropus*.

With reference to the angle of inclination *Sinanthropus* (adult and juvenile) occupies the lowest position in the line of evolution of hominids known hitherto. The Neanderthal group approaches it but the angle is clearly less acute in the latter.

2. The height of the alveolar and basal parts. One of the most striking differences between monkeys or apes and man is the difference in size and thickness between the alveolar and basal parts of the mandibles in the whole anterior region before the first molar. As stated earlier in this publication (p. 38 & ff.) the reason for such a difference is the fact that the teeth of apes and their roots are much larger and stronger than in man. This is especially true for the canines. The natural consequence after each reduction in the size of teeth is a corresponding reduction of the alveolar part which supports the teeth, whereas the basal part which serves only as a buttress for the masticatory pressure and as a working point for the mimetic (and indirectly also for the masticatory) muscles is not involved. On the contrary, the basal part is strengthened on account of the increase of the more direct working masticatory pressure to which it is submitted as a result of the retraction of the frontal teeth in conformity with their reduction. Here again the reader is referred to my earlier publication (1934) in which all these problems are dealt with.

Exact measurements of the size of the parts in question are difficult to obtain on account of the absence of a clear boundary between them. Only one point affords a landmark for such a measurement, namely the opening just above the site of attachment of the genioglossi where in anthropoids as also in man a small vessel enters the bone and thereby forms the foramen supraspinosum. The part above this canal belongs to the alveolar process, the part below it to the basal part of the jaw.

In textfigure 30 this foramen is marked by a point on the inner outline of the symphysis. The perpendicular to the incision-gnathion-line erected at this particular point supplies a good approximation of the apportioned size to each of the two parts mentioned above. This apportioned size can be expressed in the form of an index showing the distance of the foot-point of the perpendicular from the gnathion in proportion to the entire length of the incision-gnathion-line. The lower the index figure, the smaller the basal part and vice versa.

In the following table the indices are computed on the basis of the outline of the symphysis illustrated in textfigure 30 and arranged in sequence.

TABLE VII

Index of the position of the foramen supraspinosum

Chimpanzee	15.8	
Gorilla	22.2	
Heidelberg	25.8	(30.3)
Orang	27.9	
Sinanthropus H I	30.2	
Sinanthropus B I	31.3	
Krapina H	32.6	
Krapina J	34.2	
Australian	36.5	
Spy I	45.3	
Choukoutien (No. 101)	45.5	
Average of all races of recent man	47.6	

In this list the Heidelberg jaw reveals a very low figure but I doubt its correctness because of the difficulty of finding the right position of the foramen on the cast. A computation on the basis of Schoetensack's (1908) reproduction of the jaw yields an index of 30.3 which agrees with that of *Sinanthropus* H I. In respect to the latter the table shows that *Sinanthropus* ranks between the anthropoids and the Neanderthal with regard to the size of the basal part.

In my publication on the chin (1934) I referred in this connection also to the position of the foramen mentale. This foramen is situated in a much higher level in recent man than in monkeys and anthropoids. The indices obtained are as follows:

Recent man (average of all races)	46.6
Recent man according to H. E. Schulz (1933)	37-48
Anthropoids	31.3
Symphalangus	30.8
Other catarrhines	22.0

These differences are due to the same fact as in the case of the foramen supraspinosum, the foramen mentale being situated at approximately the boundary between the alveolar and basal part of the jaw.

Unfortunately these measurements cannot be taken in *Sinanthropus* on account of the multiplicity of this foramen, and one is at a loss to determine whether the uppermost or the lowest of the foramina corresponds to the single foramen in recent man and anthropoids. The lowest foramen yields an index of 33.3 in *Sinanthropus* jaw G I, of 35.0 in jaw H I and 33.3 in jaw A II.

3. Index of the robustness of the body. Some of the jaws of the Neanderthal group (La Naulette, Malarnaud) are remarkable by the fact that they are very low but at the same time unusually thick. According to Topinard the proportion between height and thickness is best determined by taking both measurements in the level of the foramen mentale.

The list of the indices given by Boule (1911/13) arranged from high to low is as follows:

TABLE VIII

Index of robustness of the body

Malarnaud	60.4	
La Naulette	57.7	
Heidelberg	52.9	
La Chapelle-aux-Saints	51.6	
Orang	50.8	
Gorilla	50.3	
Krapina G	50.0	
La Ferrassie	45.4	
Krapina D	44.4	
Krapina H	42.8	
Spy	42.4	
10 African negroes	42.1	average
10 New Caledonians	40.9	
10 modern Parisians	40.8	
72 Fushun-Chinese	40.0	average (according to Shima, 1933)
113 Koreans	40.9	
46 Kinai-Japanese	38.2	

The indices for *Sinanthropus* are:

	Index	Height	Thickness
Sinanthropus A II	59.4	25.6 mm	15.2 mm
Sinanthropus H I	58.4	26.0 mm	15.4 mm
Sinanthropus G I	48.3	34.0 mm	16.4 mm

The figures show that the *Sinanthropus* jaws A II and H I have the highest indices which are only slightly exceeded by that for the Malarnaud jaw. The indices are not inconsiderably higher than that of the

Heidelberg jaw, but it is important that jaw G I which, considered as a whole, is certainly the bulkiest of the *Sinanthropus* mandibles has a much lower index than the two other jaws and ranks between the jaws of Krapina G and La Ferrassie. The jaws of Malarnaud and La Naulette are considered to belong to female individuals by most of the investigators, and in my opinion *Sinanthropus* jaw A II and H I also belong to females while jaw G I is that of a male individual. The height of the *Sinanthropus* jaw G I is greater than the other. Thus, it becomes evident that male individuals have a lower index than females which apparently is a consequence of the former having higher mandibles. Such differences hold good not only for fossil hominids but also for recent man. Shima (1933) computed the average index in question for Fushun-Chinese and Koreans as follows:

Fushun Chinese	♂	38.4
	♀	41.7
Koreans	♂	39.4
	♀	42.4

Whereas the average thickness of the mandible of both sexes is about the same: Chinese 12.2 and 12.1, Koreans 12.3 and 12.1, the average height differs in favor of the males: Chinese 32.3 and 29.3, Koreans 31.6 and 28.9. When comparing the indices of the various jaws of the Neanderthal group, it can be easily seen that the higher the index of robustness is, the lower the jaw itself will be.

	Height	Index
Malarnaud	24.0 mm	60.4
La Naulette	26.0 mm	57.7
Spy	33.0 mm	42.4
Krapina H	35.0 mm	42.8

For anthropoids the corresponding figures are as follows:

	Height	Index
Orang	43.7 mm	50.3
Gorilla	42.7 mm	50.3
Chimpanzee	33.5 mm	48.9

The jaws of orang and gorilla which are very high are relatively thinner than those of hominids. All these facts should be taken into consideration when making a comparison of the indices in question.

However, when considering the various groups concerned by computing the average indices, it becomes evident that *Sinanthropus* has a much higher index of robustness than the Neanderthal group and recent man: *Sinanthroups* 55.4, Neanderthal group including the Heidelberg jaw 49.7, recent man 41.3.

B. MEASUREMENTS OF THE RAMUS.

1. The angle of the mandible. By this name the angle formed by the basal tangent of the mandible and the tangent of the posterior border of the ramus is designated. The measurements taken and listed below are computed on the basis of exact profile drawings (compare textfigs. 68-70, 73).

On page 72 & f I have called attention to the difficulty to determine the correct course of the basal tangent in such cases where the basal margin is curved, and attention was also called to the varying appearance of the border in the region of the angle (compare textfig. 65). The difficulties caused by all these irregularities are, of course, not decreased by the method of measurement I used. Inspite of the inaccuracy inherent to the angle, it offers a rather characteristic feature of comparative value of the mandible. Some recent author suggested the use of other landmarks which according to them are more reliable. The difficulty of undertaking changes as suggested lies in the fact that in doing so all the earlier computed figures will lose their values for comparative purposes. For this reason I prefer to use the old method.

TABLE IX

Angle of the mandible of adult individuals arranged according to size

Sinanthropus G I	97°
Gorilla	98.6° (average)
Heidelberg	107.0° (Schoetensack)
Sinanthropus H I	108.0°
Orang	108.8° (average)
La Ferrassie	109.0° (Boule)
Malarnaud	109.0° (Hamy)
La Chapelle-aux-Saints	110.0° (Boule)
Wadjak	111.0°
Predmost ♂	113.0°
Prehistoric Chinese ♂	117.0°
Choukoutien	117.0°
Krapina 1	117.0°
Australian	119.0°
Obercassel ♂	120.0°
Choukoutien ♀	120.0°
Chinese (prognathous)	120.0°
Chimpanzee	125.0° (average)
Predmost ♀	127.0°
Average figures of different races of modern man, in particular Mongol groups:	
Formosian	120.4° (105-131) (Schulz)
South American Indians	121.8° (106-133) "
Chinese ♂	118.0° (105-135) (Haberer)
Chinese ♀	129.2° (105-135) "
Lapps ♂	122.6° (105-140) (Schreiner)
Lapps ♀	125.2° (107-142) "
Koreans ♂	123.2° (Shima)
Koreans ♀	128.5° Mijamoto (Shima)
Kinai-Japanese ♂	123.0°
Kinai-Japanese ♀	129.3°
Eskimo	124.4° (100-149) (Fürst & Hansen)
Ainu	125.0° (100-140) (Koganei)
Hokuriku-Japanese ♂	128.2° (Ostuki) (Shima)
Hokuriku-Japanese ♀	134.5° "
Baining (New Pommern)	115.8 (100-132) (Schulz)
Australian	124.0° R. Martin
Negro	125.0°
European (Munich)	128.0°
European (Alsatian) ♂	122.3° Adams
" " ♀	124.4°

These figures show that a great individual variability exists, ranging from 100° to 149° in the case of the Eskimo. According to R. Martin (1928) the range of variability in recent man is still greater and begins at 88°.

On account of such conditions it seems impossible to define a standard angle for primitive forms. Furthermore, even in anthropoids the angle varies from 95° (gorilla) to 128° (chimpanzee). However, chimpanzee shows what may be taken as the reason for such a great difference in anthropoids. As seen in textfigure 73 there is also a difference in the direction of the alveolar and basal line in both apes. In the gorilla these lines run almost parallel or more correctly, they form an angle of 3°, but in chimpanzee they converge backward to form an angle of 10°. This convergence is obviously a consequence of the difference in the height of the body. In gorilla (textfig. 73 a) the vertical symphyseal height is only insignificantly greater than the height of the body behind M_3, namely 39 to 34 mm, whereas in chimpanzee (textfig. 73 b) the figures of the same measurements are 38 to 27 mm. This question will be discussed below. The reason for such a difference in the height seems to be that in chimpanzee the teeth of the frontal part, not only the canines but also the incisors, are relatively much stronger than the molars, whereas in gorilla and orang these differences are remarkably less pronounced. The mandible serving as a lever during mastication therefore requires a different construction adapted to the corresponding working points.

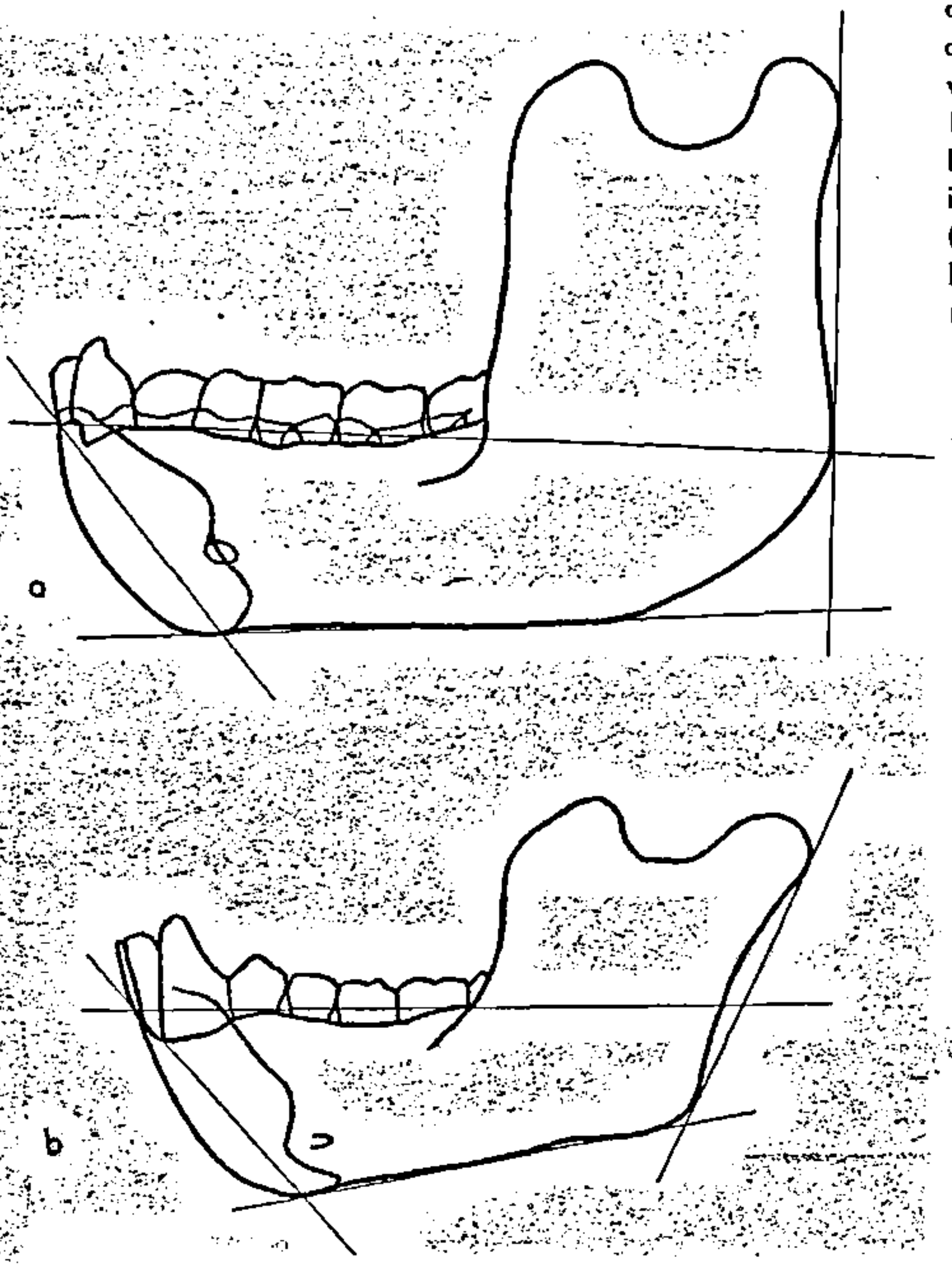


Figure 73. Diagrams of gorilla ♀ (a) and chimpanzee ♂ (b) mandibles in profile view, with indications of the median sections through the symphysis in correct orientation and projection to the alveolar plane. The lines of orientation are represented by fine lines. × 2/3.

The figures of Table IX show that quite apart from *Sinanthropus* the average degree of the angle is about 110° in the Neanderthal group and 123° in modern man; perhaps this angle is even slightly smaller in palæolithic man (118°). There is every reason to believe that a steep ramus is characteristic for a primitive hominid and that it becomes more inclined in the course of evolution. The conditions known to exist in *Sinanthropus* agree very well with such a hypothesis. In that case the average — if it is permitted to speak of an average with only two specimens on hand — is 102.5°. The line of evolution therefore is as follows:

Sinanthropus	102.5°	averages
Neanderthal group	110.0°	
Recent palæolithic man	118.0°	
Modern man	123.0°	

Werth (1928) asserted that in respect to the angle in question the Neanderthal group would be more progressive than palæolithic recent man, the first having a more obtuse angle than the last named. He proves his assertion by referring to the mandibles of La Chapelle-aux-Saints, Le Moustier and the Ehringsdorf child on the one hand, and to those of Combe Capelle and Cro-Magnon (old man) on the other. The angle of the La Chapelle-aux-Saints mandible is 110° according to Boule, that of Combe Capelle 114° according to Klaatsch (1910) and that of Cro-Magnon 119° which is entirely contradictory to Werth's statement. The reference to the mandible of Le Moustier and to that of the Ehringsdorf child is not applicable in this case since both jaws belong to juvenile individuals, where, as is well known, the ramus always forms a more obtuse angle with the body than it does in adult jaws, as for instance in Combe Capelle and Cro-Magnon. The angle of Le Moustier is 118° and that of the Ehringsdorf child 116.5°; the determination of both angles is after H. Virchow (1920). Mandibles of recent palæolithic man of the same age as those quoted immediately above are not known so that we are confined to compare them only with material belonging to recent man.

Kieffer (1908) defined the degree of the angle in different periods of life. His method was somewhat different from the one ordinarily used, with the result that his definitions are not directly comparable with those obtained by other methods. However, his figures for juvenile and adult jaws can be used for comparative purposes. According to the figures obtained by Kieffer the angle averages 126.5° in different juvenile individuals of the same age and 123.0° in adults of the same population. Considering this deviation which is dependent upon the age of the individual, it is found that the mandibles of Le Moustier and Ehringsdorf agree quite well with the adult jaws of Krapina and in any case their angles are incontestably more acute than those of recent man. Thus, it becomes evident that Werth's assumption was without any real foundation. With reference to *Sinanthropus*, there are two juvenile jaws, namely B I and F I, which permit a definition of the angle in question. Both jaws belong to individuals of approximately 8 to 9 years old. The angle of jaw B I is 107°, that of F I 112°. The mandibles of recent Mongols of corresponding age at my disposal have an angle of 123° to 135°. Kieffer's average figure of South German children of the age from 5 to 10 years is 125.3° (121-132). In the following table available figures of juvenile mandibles of about the same age are listed as follows:

TABLE X

Angle of the mandible of juvenile individuals arranged according to degree

Sinanthropus B I	107°
Gorilla	109°
Sinanthropus F I	112°
Orang	113° (average)
Ehringsdorf child	116.5°
Le Moustier	118°
Chimpanzee	122° (average)
Recent European man	121-132° (Kieffer)
Recent Mongols	123-135°

It becomes evident that *Sinanthropus* has a more erect ramus in the juvenile stage than the Neanderthal and recent man.

It is not without interest that the angle is more acute, which means that the ramus is more erect in the male than in the female individual of recent man. According to Kieffer (1908) the figures obtained are: male 121°, female 124.5°. For the Lapps, Schreiner (1935) obtained the following figures: male 122.6, female 125.2. In Koreans and Japanese this average sex difference amounts to 5.2° and 6.1° respectively (see Table IX). In the light of these statements the writer believes that it is not accidental that *Sinanthropus* jaw G I, supposed to belong to a male individual, has an angle of 97° and jaw H I, supposedly that of a female, one of 108°. Obviously, a steeper ramus belongs to a bulkier body.

2. The height-breadth index of the ramus. Some investigators lay special stress on the height-breadth index of the ramus, and consider a high index as a primitive character. Yet as Boule (1911/13) remarked correctly, the index has no taxonomic significance on account of the absence of a fundamental difference between apes and man. In addition, it becomes evident from the following table that the individual variation in the same group of population of recent man, in Eskimo for instance, can be so great as to embrace all the different individual indices of anthropoids and hominids.

TABLE XI

The height-breadth index of the ramus arranged according to size

Eskimo No. 189	82.2 (Fürst and Hansen)
Eskimo No. 200	82.2 "
Eskimo No. 112	79.6 "
Eskimo No. 373	77.9 "
Heidelberg	75.0 (Schoetensack)
Choukoutien ♀	74.2 (Weidenreich)
La Chapelle-aux-Saints	71.4 (Boule)
Orang	71.3 (average)
Predmost ♀	71.0
Chimpanzee	70.0 (Boule)
Sinanthropus B I	69.8 (Weidenreich)
Combe Capelle	69.0
Choukoutien ♂	67.8 (Weidenreich)
Sinanthropus H I	67.3 (")
Cro-Magnon	66.6 (Boule)
La Ferrassie	66.0 (")
Wadjak II	65.4
Gorilla	65.0 (average)
Eskimo	65.0 (average) (Fürst and Hansen)
Predmost ♂	64.5
African negroes	63.4 (Renard)
New Caledonians	63.4 (")
Sinanthropus G I	60.8 (Weidenreich)
Lapps	60.1 (Schreiner)
Obercassel ♀	60.0 (Bonnet)
Australian	59.6 (R. Martin)
Malarnaud	58.5 (Boule)
Krapina (without designation)	57.5
Norwegian	56.5 (Schreiner)
Obercassel ♂	56.0 (Bonnet)
European	53.4 (Renard)
Eskimo No. 227	48.8 (Fürst and Hansen)

Werth (1928) asserted that the Heidelberg jaw with an index of 75.0 was completely outside the range of variability of the entire family of mankind. The table shows that this is not actually the case. Among the figures given for recent Eskimos by Fürst and Hansen (1915) there are many that exceed considerably the Heidelberg mandible index and again many which approach it. The same is true for the Lapps according to the figures obtained by Schreiner (1931). On page 74 & f I already referred to these and other figures. Table XI reveals that not only *Sinanthropus*, the Neanderthal group, palæolithic recent and modern man but also the anthropoids represent a great variability so that it is impossible to determine the real order of evolution. It seems that the breadth of the ramus depends on individual characters and development of the masticatory muscles rather than upon a special phylogenetic factor.

Schulz (1933) determined that the Württembergian have a very high and narrow ramus (low index: 49.5) and the negroes a very low and broad ramus (high index: 62.1). As the figures of Fürst and Hansen (1915) prove the Eskimos also have a much higher average index (65.0) than the European (53.4). The only conclusion which may be drawn from these computations is that people or races with strong masticatory muscles have relatively lower and broader rami than those with more weakly developed muscles. However, on the other hand it should be recalled that the male *Sincnthropus* G I the mandible of which shows all characters of robustness and a very strong musculature has a lower index of the ramus than the female and weaker *Sinanthropus* jaw H I. It is remarkable that the same is true for palæolithic man: in the three cases where we have male and female individuals — Predmost, Obercassel and Choukoutien — the jaws of females have a higher index than the males (compare Table XI), the differences amount to 4-10 units.

According to Schreiner (1935) there is also a difference in sex in the modern Lapps, the average index of the females being 61.0 and that of the males 58.6. For the Chinese, Koreans and Japanese the reader is referred to Shima's computations (1933) which read as follows:

Fushun Chinese	♀	58.2	
	♂	53.8	
Korean	♀	59.5	
	♂	57.1	
Kinai-Japanese	♀	57.6	Mijamoto
	♂	56.2	

Schreiner's figures reveal that this appearance is a consequence of the greater difference in height (♀ 51.8 mm, ♂ 57.8 mm) than in that of breadth (♀ 31.6 mm; ♂ 33.9 mm) and the same holds good for the Chinese, Koreans and Japanese. In *Sinanthropus* the female jaw H I has approximately the same breadth as the male jaw G I (39.7 mm; 40.7 mm) while the difference in height is much greater (59.0 mm; 66.7 mm). Therefore the index depends more on the height than on the breadth of the ramus. Female jaws have a higher index on account of the ramus being lower than that of male individuals which is in conformity with the statement with reference to the index of robustness, namely that the body of the jaw is also lower in females than in males (p. 87). Races with low rami have a higher index than those with high rami. A decision as to whether the low or the high ramus should be considered a more primitive character cannot be reached, since this character is completely overshadowed by much more pronounced sex differences.

3. The incisura semilunaris. Werth (1928) laid great stress upon the depth of the mandibular notch and the exact position of its deepest point. From the fact that mandibles of carnivores, the rami of which according to Werth would have preserved an extraordinarily primitive form, also show a notch of moderate depth, that

author deduces that the deepening of the notch should be tantamount to a progressive development. Furthermore he assumes that the position of the deepest point behind the middle of the notch, that is to say, nearer to the condyle, would be a primitive character and he attempts to prove this by figures obtained for insectivores and prosimians.

In his figures 209 which is reproduced here as textfigure 74 I Werth illustrates a series of notches with such pretended progressive tendencies ranging from the Heidelberg jaw as representative of the most primitive hominid to recent man. In regard to this feature in *Sinanthropus* the mandibular notch is in all cases (G I, H I, F I) of the same depth as is the rule for recent man. Thus Werth's series appear to illustrate nothing else but a great illusion; one can easily group other specimens of the corresponding stages of evolution with just the opposite effect. In textfigure 74 II *Sinanthropus* H I displays a much deeper notch than the Eskimo, the Krapina jaw I likewise has a much deeper notch than Le Moustier. In order to verify this condition, I computed the notch index, that is to say. the depth of the incisura in relation to its length, as listed in Table XII. For recent man figures obtained by Shima (1933), H. E. Schulz (1935), and Keiter (1936) are included in the table.

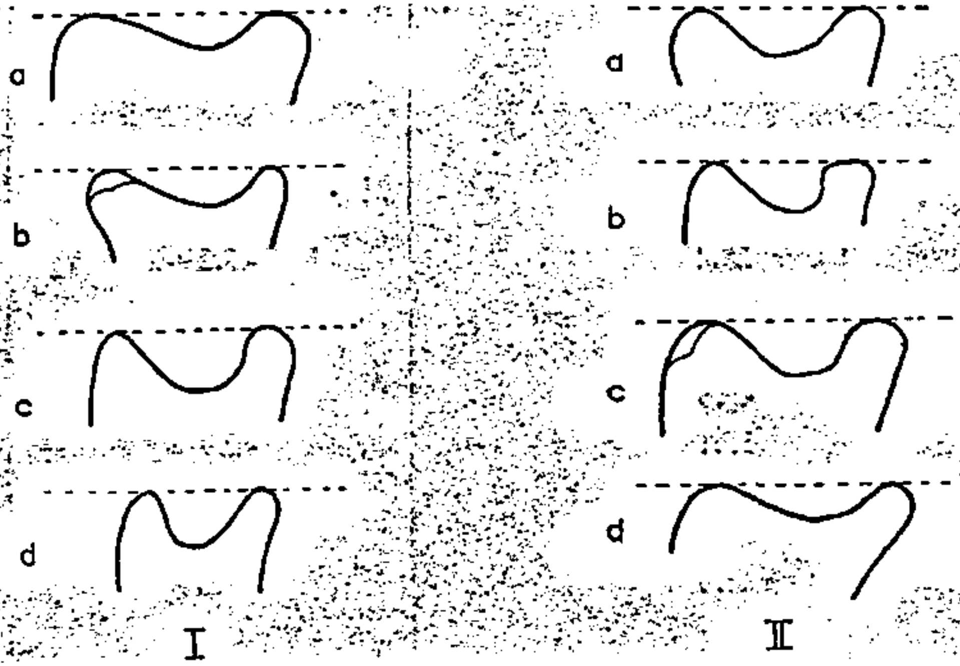


Figure 74. Outlines of the mandibular notch and of the two processus. Designations:— I a-d after Werth's (1928) figure 209: a, Heidelberg; b, Le Moustier; c, Combe Capelle; d, modern man. II a-d represent notches in almost reversed order to fig. I: a, *Sinanthropus* H I; b, Krapina I; c, Wadjak II; d, modern Eskimo.

The figures of Table XII show clearly that there is no fundamental difference in respect to the depth of the mandibular notch between anthropoids, fossil hominids and recent man. Its shallowness in the case of the Heidelberg man is exceptional and depends upon the anomalous breadth of the ramus as stated above but it may also occur in recent man: the resent Eskimo listed at the end of Table XII has a still more shallow notch than the Heidelberg man. On the other hand, the figures of anthropoids demonstrate not only the great variability but also the fact that the shallowness is not at all primitive as the male gorilla exhibits a very deep and narrow notch. Werth's statements about the carnivores cannot be applied to the primates.

As to the position of the deepest point Table XII reveals that its location varies considerably in anthropoids, but it is generally situated closer to the coronoid process than to the condyle, a condition which certainly is at variance with Werth's supposition of primitiveness. H. E. Schulz (1933) found the deepest point of the notch of recent man in 66-74% (according to the race) near the coronoid process and maintains that his investigations do not confirm Werth's assumption. Keiter (1936) obtained the same results for recent Australian and Melanesian.

The Heidelberg jaw served as basis for both of Werth's assertions because he considered it a genuine primitive type of the hominid mandible. As shown above repeatedly, *Sinanthropus* demonstrates the error of forming

TABLE XII

Notch Indices

	Depth-length index	Index of the position of the deepest point*
Gorilla ♂	76.7	51.7
Gorilla ♀	42.8	72.8
Orang ♂	41.0	41.6
Orang ♀	34.8	60.0
Chimpanzee ♂	35.5	66.2
Sinanthropus H I	50.6	36.9
Sinanthropus G I	36.4	49.9
Sinanthropus F I	30.8 ?	51.2 ?
Heidelberg	18.4	41.7
Malarnaud	21.7	50.2
Le Moustier	28.4	47.2
Ehringsdorf child	35.9	45.2
Krapina (without designation)	36.8	41.4
Krapina K	47.5 ?	56.7
La Quina	37.1	42.9
La Chapelle-aux-Saints	36.2	52.3
Average of 9 *Homo sapiens fossilis*	40.4	52.8
Recent Man:		
Australian	31.1	
Melanesian	35.2	
Negroes	37.9 average	
Egyptian	36.0	
American Indians	40.2	
Fushun Chinese ♂ and ♀	39.9	
Koreans ♂ and ♀	41.2	
Kinai-Japanese ♂ and ♀	38.9	
European (Württembergian)	41.9 (28.6-57.1)	
Eskimo ♂	17.4	44.6

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* Figures higher than 50 imply that the deepest point is situated before the center, that is to say, near to the coronoid process.

such a presumptoin and it also shows that the peculiarities of the mandibular notch in question bear no comparative significance.

4. Relation between bicondylar and bigonial breadth. H. Virchow (1920) called attention to the fact that the ramus in the Ehringsdorf child inclined strongly lateralward, the bicondylar breadth being wider than the bigonial breadth. According to Boule the mandibles of La Chapelle-aux-Saints and La Ferrassie agree with the Ehringsdorf fossil in this respect. The same is true of the Heidelberg and Krapina jaw I. The narrower the bigonial breadth is in relation to the bicondylar breadth the greater the inclination of the ramus will be. This relation can best be demonstrated by computing an index for the breadth of the mandible.

TABLE XIII

Relation between bicondylar and bigonial breadths arranged in the order from high to low

	Bicondylar breadth	Bigonial breadth	Index
La Chapelle-aux-Saints	147.3	99.2	67.4
Sinanthropus G I	146.4	108:6	74.1
Krapina I	146.5	111.0?	75.7
Sinanthropus B I	108.2	88.3	81.6
Heidelberg	129.8	107.9	83.1
Choukoutien 101 ♂	137.0	121,4	88.8
Sinanthropus H I	101.8	97,8	95.5
Obercassel ♂	133.0	134.3	101,2

Measurements made on recent human jaws at the suggestion of H. Virchow proved that the index varies from 83.5 to 124.7. In Anthropoids the index ranges between 85.0 and 95.0, only in male orangs it exceeds the 100 mark.

However, it must be understood that this index depends to a large extent also on the more or less lateral projection of the condyle and not on the inclination of the ramus alone. Therefore H. Virchow measured the bicondylar breadth by placing the calipers on the middle of the condyle and not on the most laterally projecting point. In each case the result will be the same in principle. The ramus of the mandible may incline laterally or medially or be erect. As is seen in *Sinanthropus* (Plate XV, figs. 1-3) a ramus with a not too strong lateral inclination is to be considered as a primitive feature which would be in conformity with the appearance of the ramus in anthropoids.

C. MEASUREMENTS OF THE MANDIBLE AS A WHOLE.

1. Alveolar and basal plane. Schoetensack (1908) compared the Heidelberg jaw with that of a European and a negroe by means of a diagram in profile view, superposing the three jaws in the alveolar plane orientation. This diagram has been taken over by many other more recent investigators. Schoetensack calls attention to the fact that the basal line, that is to say, the tangent of the lower margin runs parallel with the alveolar line in recent European, but forms an angle opening posteriorly to this line in the Heidelberg jaw. This angle is 14° in the Heidelberg jaw. Schoetensack thinks that the appearance of the latter is a primitive feature and that the parallelism of both planes should be considered as an indication of an advanced stage.

This belief is undoubtedly erroneous. In anthropoids there is a difference in this regard between gorilla and orang on one side and chimpanzee on the other as stated above (see p. 89 and textfig. 73). In both of the first mentioned apes the planes are approximately parallel or form an angle of about 3-5° (textfig. 73 a). In chimpanzee this angle is higher and may reach more than 10° (textfig. 73 b). The reason for this difference is, I believe, that in chimpanzee the molars are much smaller in relation to the frontal teeth, especially the canines, than in gorilla and orang. In the first therefore the symphyseal part is higher than the molar part while it is the same or only slightly higher in the latter. Recent man shows a different appearance in this respect. According to H. Virchow (1920) low jaws also have a low symphysis; high jaws have a high symphysis. However, I have found that in the latter the molar part is relatively lower so that the basal line must form a more or less acute angle with the alveolar line. The same features in chimpanzee and recent man nevertheless must have a different bearing. For the first one mentioned the reasons just stated are valid, while in the case of the latter where the frontal teeth are much more reduced in size than the molars, the symphyseal height seems to be the effect of the rising of the basal part in the course of the formation of the chin, a condition which compensates the reduction of the alveolar part.

In all available *Sinanthropus* specimens both lines in question are almost parallel (textfig. 75). In *Sinanthropus* jaw H I they form angle of less than 1°, in jaw G I even the molar height is slightly more than that of the symphysis so that the angle becomes obtuse (about -1.0°). The latter feature is still more pronounced in *Sinanthropus* jaw B I where this angle reaches 4°. It is evident that the strong inclination of the basal line in the case of the Heidelberg jaw (textfig. 75) is caused by the presence of a deep incisura submentalis or better by

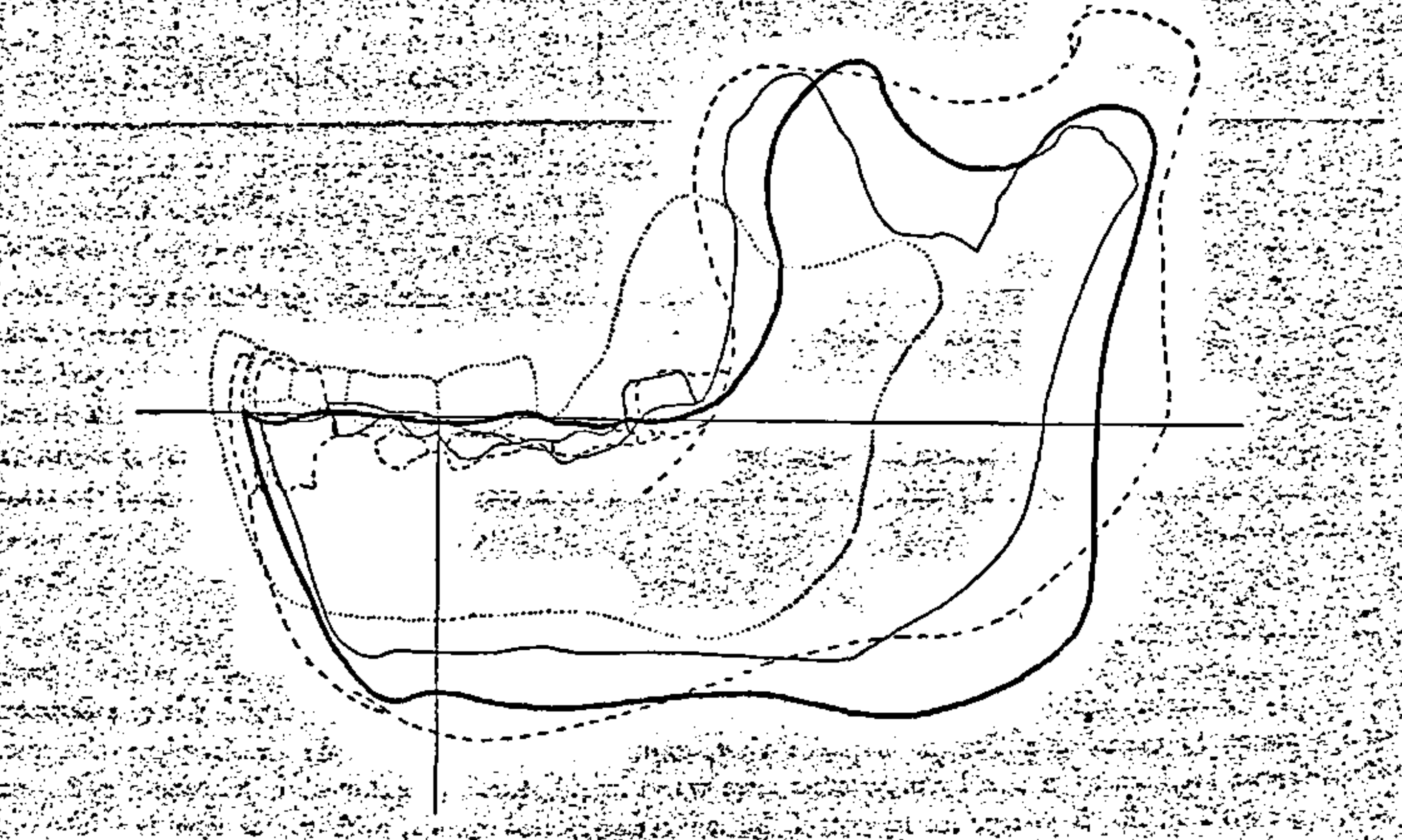


Figure 75. Profile views of three *Sinanthropus* mandibles compared with that of the Heidelberg jaw, all oriented in the alveolar plane and the "postlacteon" perpendicular. — *Sinanthropus* G I; —— *Sinanthropus* H I; .... *Sinanthropus* B I; - - - Heidelberg. Natural size.

the strong projection of the torus marginalis and not by an excessive symphyseal height. Some of the jaws of the Neanderthal group agree more or less with the Heidelberg jaw but, in accordance with their less pronounced torus marginalis, the inclination is less marked. In any case *Sinanthropus* represents in the character discussed here a more primitive type than the Heidelberg jaw. All statements made in connection with the special appearance of the torus marginalis and the incisura submentalis of the latter hold good also for the special course of its basal line.

2. Height of the body and ramus. It is a matter of routine that all measurements of the jaw contain the height of the symphysis even though it is of very moderate comparative value. In this respect I fully agree with H. Virchow's criticism (1920). Only the relation of this height to other parts of the body or to those of the ramus may have some significance. In the preceding paragraph the relation between the symphyseal height and that of the molar region was discussed. However, it is not without interest to note also the relation between the height of the body in the latter region to that of the ramus.

From textfigure 73 a it is apparent that in gorilla the height of the ramus — represented by a line perpendicular to the alveolar plane drawn from the vertex of the coronoid process to the lower margin — exceeds considerably that of the body measured in the same way behind M_1. The difference in height is much less in chimpanzee (textfig. 73 b) or in recent man. In the gorilla the average index of the body height in relation to the ramus height is 34.6 (31.3-39.2) while it reaches an index of 47.7 (33.7-59.8) in recent man (Chinese). In the latter the ramus is relatively higher in low jaws. In orang the average index is 40.0 and in chimpanzee 46.2.

In *Sinanthropus* H I the index is 36.2, which is close to the lowest margin of recent man, and falls within the range of variation for the gorilla. This condition is not without significance because of the robustness of the jaw whereas in recent man only weakly developed jaws have an equally low index. In *Sinanthropus* G I the index is, it is true, 44.0, that is one which represents a high mark in respect to the robustness of this mandible (compare p. 86). In the Neanderthal group the average index is 46.9 (44.8-50.0), which is higher than that of *Sinanthropus*. The Heidelberg jaw with an index of 46.8 resembles recent man in this respect.

3. The mandibular index. By mandibular index there is implied the rate of the length of the mandible to the bicondylar breadth. The length is represented by a straight line uniting the most prominent part of the chin with the middle of the bigonial breadth. Measuring the length in this way is contestable when viewed from a comparative standpoint, since in anthropoids and fossil hominids in which a chin is absent the foremost point of this measurement is not definable. Besides, the length of the mandible comprises two parts, namely the length of the body and the breadth of the ramus, both of which vary independently from each other.

To avoid such difficulties in defining the landmark, I have chosen as the representative length the alveolar line from the incision to the crossing point with the ramus tangent as determined on the diagram in profile view (textfig. 68). In the following table are grouped those jaws on which the respective measurements could be taken. Of course, these figures cannot be compared with those obtained by the usual method.

The figures reveal that the index of hominids depends to a great extent on the mandibular breadth, while the length is more irrelevant. A great difference exists between *Sinanthropus* jaw G I and H I in the bicondylar breadth which amounts to 146.4 mm in the first and to only 101.8 in the latter, while the length is 103 and 94 mm respectively. Narrow jaws therefore have higher indices than broad ones regardless of the length. On the other hand it may occur that the bicondylar breadth is the same whereas the length differs considerably. This is the case, for instance, in a prognathous Chinese, and in the woman of Obercassel listed in Table XIV as having a breadth of 122 and 123 mm respectively, but the length of the first mentioned is 93 mm and that of the last 76.5 mm.

TABLE XIV

The mandibular index

	Length	Breadth	Index
Gorilla	139.0 mm	120.0 mm	115.7
Orang	118.5 mm	115.5 mm	102.4
Chimpanzee	108.0 mm	109.0 mm	98.8
Sinanthropus H I	94.0 mm	101.8 mm	92.4
Le Moustier	104.0 mm	119.5 mm	86.8
Predmost ♀	92.0 mm	108.0 mm	85.2
Heidelberg	109.0 mm	129.8 mm	84.0
Australian	91.0 mm	113.0 mm	80.5
La Chapelle-aux-Saints	112.0 mm	147.5 mm	75.8
Chinese ♂ (prognathous)	93.0 mm	122.0 mm	75.5
Wadjak II	107.5 mm	144.0 mm	74.6
Sinanthropus B I	80.0 mm	108.2 mm	73.8
Eskimo	91.0 mm	125.0 mm	72.7
Palæolithic Chinese	86.0 mm	121.0 mm	71.1
Krapina I	104.0 mm	147.0 mm	70.7
Predmost ♂	98.0 mm	139.0 mm	70.5
Sinanthropus G I	103.0 mm	146.4 mm	70.3
Choukoutien ♀	86.5 mm	127.0 mm	68.2
Chinese child No. 44	73.5 mm	108.8 mm	67.5
Obercassel ♂	86.0 mm	135.0 mm	63.7
Choukoutien ♂	86.5 mm	137.0 mm	63.2
Obercassel ♀	76.5 mm	123.0 mm	62.2

Furthermore, it is evident from these figures that the index does not offer a clear indication as to the course of evolution, for *Sinanthropus*, Neanderthal and recent man (fossil and modern) are mingled and there is no sharp boundary between the single groups. Werth (1928) believes that man descended from a form similar to *Propliopithecus* which combines a considerable bicondylar breadth with a relatively long jaw and would have nothing in common with anthropoids and their exaggerated long snouts. I estimate the mandibular index of *Propliopithecus* as being about 70-75 which means that it falls within the range of hominids. However, the whole problem will be better discussed in connection with the shape of the mandibular arches which is being dealt with in the following section.

4. The mandibular arches. The most characteristic appearance of a mandible is the form of its arch. As a matter of fact, not one but three or even four arches are recognizable, each distinctly different from the other. The three arches are known under the terms: dental arch, alveolar arch and basal arch. H. Virchow (1916, 1920) in particular has described these arches in detail and also devised the most suitable methods for the proper determination by drawing and measurement.

The dental arch is the arcade formed by the teeth, that is, by the teeth viewed from the occlusal surface. Its special shape depends considerably upon the conditions of the teeth, namely the degree of attrition and the particular position of the individual tooth. For instance, a dental arch with incisors inclined forward — "Klinodontie" after Virchow — will show a form different from that with erected incisors, although in both cases the curvature of the mandibles proper may be the same. In the following drawings and descriptions the dental arch is in all cases represented by a connecting curve coursing along the edges of the incisors and the tips of the labial cusps of the premolars and molars.

The alveolar arch is formed by the horseshoe-like area occupied by the respective alveoli with their labial and lingual limits serving as boundaries. With the aid of Schwarz's stereograph it is possible to determine these limits also in cases where the teeth are still embedded in their respective alveoli.

The basal arch is represented by the deepest line running along the lower border of the mandible from about gonion to gonion. According to Virchow's suggestion, it can be defined by leading a pencil along the most prominent ridge of that border.

The fourth arch, usually overlooked, is the curvature on the inner contour of the mandible in occlusal view. It corresponds to the outline of the torus alveolaris and represents the narrowest embracing curve of the inner space of the mandible. In all cases in which the torus alveolaris and the torus transversus superior are well developed this arch is a characteristic feature. Above (p. 43) it was called the "inner mandibular arch."

The three first named arches can be illustrated by drawings in a very simple way using Schwarz's stereograph. The mandibles are oriented in the alveolar plane and the respective curves drawn with the corresponding needles of the apparatus. To superpose the basal arch on the corresponding site of the alveolar arch it is sufficient to turn the mandible around an angle of 180° and at the same time the paper after having traced the contours.

For the determination of size and special form of the mandibular arch Schwalbe (1914) and H. Virchow (1920) believed it best to take the alveolar arch. One measures the length and the breadth, and the mandibular arch index thus obtained gives a good idea of the degree of the narrowness or width of the arch. However, I disagree with those authors in regard to the method of taking the measurements of length and breadth. As breadth I take the distance between the two most backwards situated points of the posterior end of the arch behind M_3 and as length the distance in the mid-line between the most anteriorly situated point of the arch and the middle of the just mentioned transveral line. These measurements are carried out on the drawings. The measurements obtained with this method of course differ from those given by H. Virchow and cannot be used for comparison. De Terra's (1905) dental arch index also differs from my mandibular arch index, although he took approximately the same measurement for the length but his breadth measurement includes the transversal distance of the labial surface of the teeth at their furthest projecting points.

In my publication on the origin of the chin (1934) proof was given that it is of the greatest importance to determine not only the mandibular arch as a whole but also the anterior part of it which is occupied by the deciduous teeth in childhood. The posterior boundary of the anterior part is directly before M_1. Bolk (1926) called this point "postlacteon." In the discussion below I shall use the term "anterior alveolar arch" for this pre-postlacteon arch and the reader is to understand that under the term "alveolar arch" the complete arch is meant.

No figures were computed for the dental arch since they do not deviate to any extent from those of the alveolar arch. However, it is of importance to compute indices for the basal arch. Measurements of this arch are carried out in the same way as those pertaining to the alveolar arch, the distance between the most posterior points of the basal arch in the same frontal line as that of the alveolar arch being taken as breadth of the basal arch. It is not necessary and partly also not possible to take the gonia as landmarks for the basal arch since the characteristic shape of the curve is already represented by its anterior part.

Since in most cases and for all three indices the breadth is more than the length, the index here is computed from the length in relation to the breadth and not the reverse as is commonly done.

TABLE XV

Breadth and length of the anterior alveolar arch, alveolar arch and basal arch arranged according to the size of the breadth-length-index of the alveolar arch

	Alveolar arch						Basal arch		
	anterior alv. arch			alveolar arch					
	length	breadth	index	length	breadth	index	length	breadth	index
Gorilla No. 328 ♀	39.0	42.0	92.8	86.5	53.0	163.2	53.0	64.5	82.0
Orang No. 247 ♀	38.0	43.0	88.5	71.0	46.5	152.8	46.5	58.5	79.4
Chimpanzee ♂	39.0	49.0	79.6	74.0	51.0	145.3	44.5	74.5	59.8
Australian	21.0	47.0	44.7	58.0	55.0	105.5	46.0	78.0	58.8
Sinanthropus G I	28 0	47.0	58.3	65.0	63.0	103.3	46.5	68.2	68.2
Sinanthropus H I	23.5	47.0	50.0	54.0	54.0	100.0	42.0	67.0	62.7
Ehringsdorf adult	23.0	45.0	51.0	59.5	60.0	99.2	42.0	62.0	67.6
Chinese No. 63 (progn.) ♂	23.0	44.0	52.3	59.5	61.0	97.5	47.0	89.0	52.8
Wadjak II	24.5	49.0	50.0	60.0	62.0	96.8	44.0	93.0	47.4
Sinanthropus A II	22.0	43.0	51.2	54.0	57.0	94.8	—	—	—
Heidelberg	22.5	48.5	46.3	58.5	62.0	94.3	42.0	74.0	56.7
Predmost ♂	25.0	46.0	54.3	58.5	63.0	92.8	47.0	75.0	62.7
Predmost ♀	26 0	50.0	52.0	55.5	60.0	92.5	48 0	84.0	57.2
Krapina G	23.5	50.0	46.1	59.0	64.0	92.1	42.5	70.0?	60.8
Krapina H	21.5	47.0	45.7	56.0	62.0	90.4	—	—	—
Choukoutien (104) ♀	22.0	44.0	50.0	52.0	60.0	86.7	45.0	78.5	57.3
Spy I	20.0	50.0	40.0	53.0	63.0	84.2	41.0	72.0	56.9
Eskimo ♂	20.0	45.0	44.5	50.5	60.0	84.1	46.0	90.0	51.1
Obercassel ♂	21.0	42.0	50.0	54.0	66.0	82.0	60.0	101.0	59.3
Krapina I	20.0	45.0	44.5	52.5	66.0	79.5	36.0	72.0	50.0
Chinese Kansu 404/6	21.0	47.0	44.7	50.0	63.0	79.4	47.0	81.0	58.2
Choukoutien (101) ♂	17.5	47.5	36.9	48.0	63.0	76.3	45.0	85.0	52.9
Obercassel ♀	18.0	41.0	43.8	48.0	63.0	76.2	41.0	82.0	50.0
JUVENILE:									
Chimpanzee I (381)	29.0	33.0	88.0	—	—		15.5	32.0	48.4
Chimpanzee II (321)	31.5	42.5	74.2	—	—		14.0	30.0	46.6
Sinanthropus B IV	32.5	46.0	70.5	—	—		—	—	—
Recent Chinese child I	26.0	37.0	70.2	—	—		18.0	47.0	38.3
Gibraltar child	27.5	46.0	59.8	—	—		17.0	49.5	34.4
Sinanthropus B V	28.0	48.0	58.3	—	—		—	—	—
Recent Chinese child 44 ♂	25.5	46.0	55.4	—	—		23.0	54.5	42.3
Sinanthropus B I	26.0	49.0	53.2	—	—		14.0	44.0	31.8

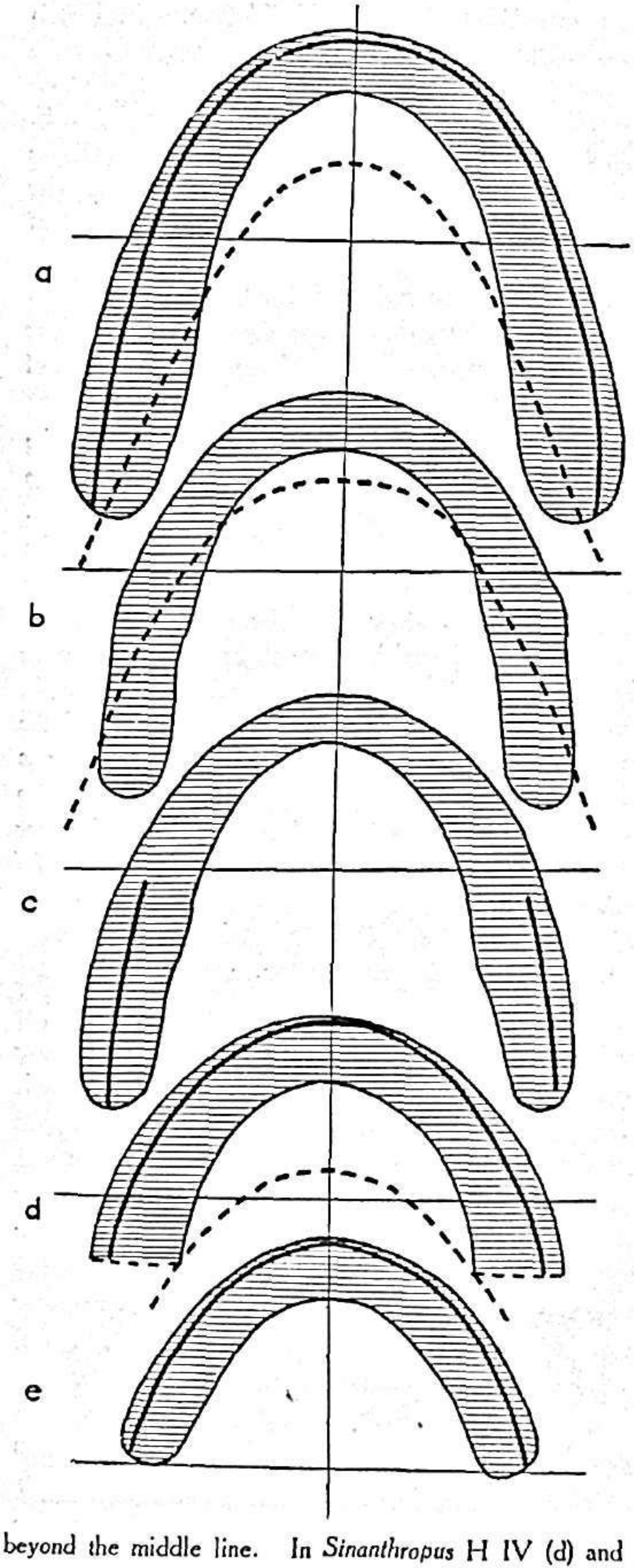


Figure 76. The mandibular arches of all the available *Sinanthropus* specimens in correct projection to the alveolar plane oriented in the middle. The "postlacteon" frontal line is traced. Alveolar arch represented by cross lines, dental arch by heavy lines, basal arch by interrupted lines. Designations:— a, male *Sinanthropus* G I; b, female *Sinanthropus* H I; c, female *Sinanthropus* A II; d, female *Sinanthropus* H IV; e, *Sinanthropus* child B V (permanent canines erupting). Natural size.

a. Alveolar arch: The alveolar arch of anthropoids is characterized by its length and narrowness, the result being a very high index which exceeds the 160 mark in gorilla. In recent man the arch is shorter and wider and therefore more V-shaped, with an index approaching the 75 mark. In chimpanzee the index though lower than in gorilla is still quite high (145). However, recent man is far from presenting a uniform aspect in this regard. In cases of prognathism the alveolar arch may be long and relatively narrow, with the result that the index is high also. In the preceding Table XV the recent Australian with an index of 105.5 and the recent Chinese with one of 97.5 represent such prognathous mandibles, whereas in cases of ortho- or opisthognathism the reverse is found to occur. Thus the indices obtained for recent man prove clearly that the shape of the alveolar arch as much as it is definable by the breadth and length only permits a judgement on the degree of prognathism and orthognathism. In the Neanderthal group the index varies from the Ehringsdorf adult (99.2) to the Krapina jaw I (79.5) and it is clearly seen that the index of the Heidelberg jaw (94.3) is exceeded by those for prognathous jaws belonging to recent man. The adult *Sinanthropus* jaw fluctuates around the 100 mark, that is to say, it reaches the uppermost limit within the range of variability of recent man with an average index of 99.4 which is distinctly higher than that of the Neanderthal group (89.9).

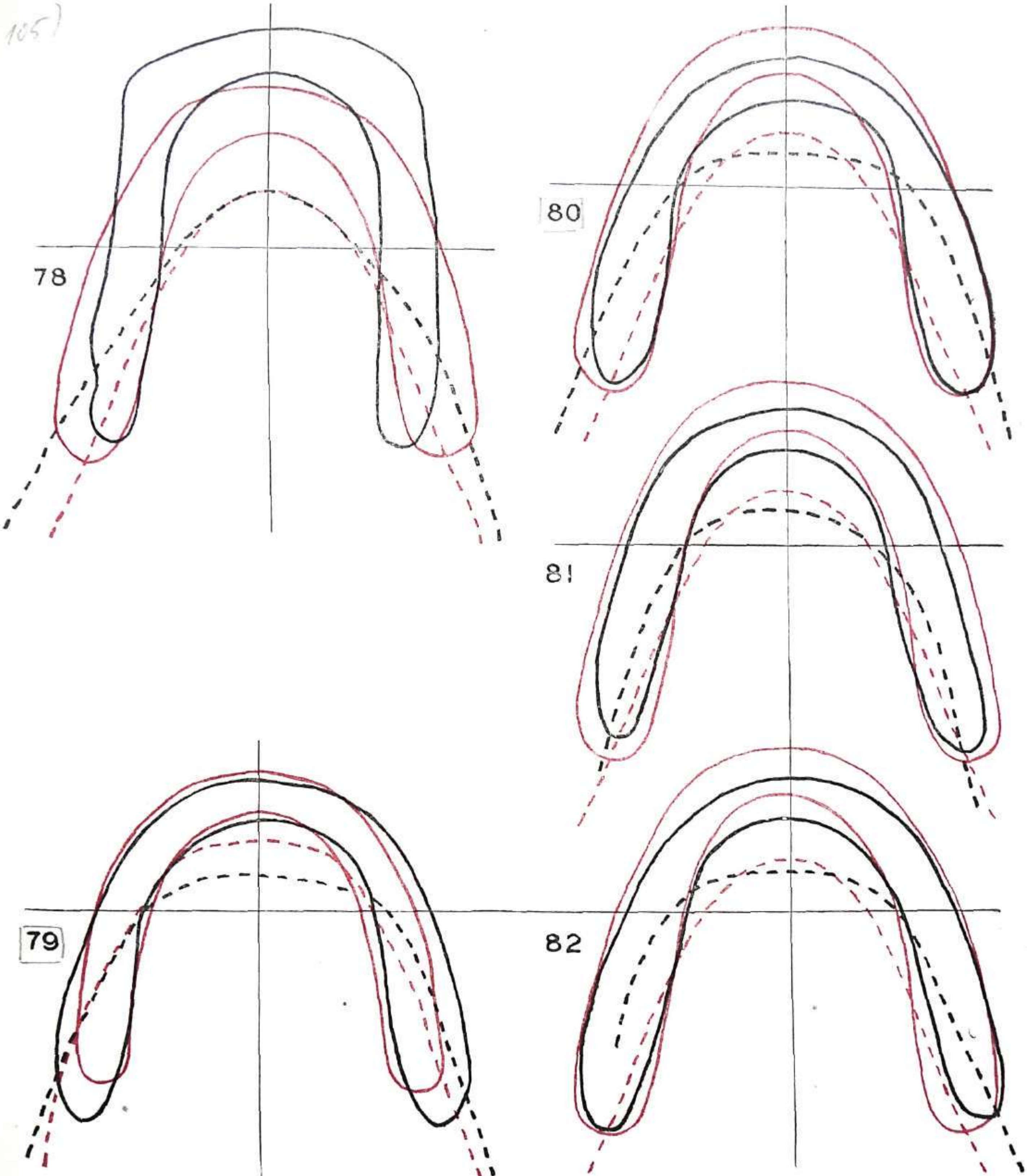
The characteristic shape of the alveolar arch of all the material available of adult *Sinanthropus* is illustrated in textfigure 76 a-e. The drawings of *Sinanthropus* jaw G I and H I were derived from the reconstructed jaw. In the case of *Sinanthropus* A II (textfig. 76 c) the arch was completed by copying symmetrically the preserved right side and continuing the course of the curvature beyond the middle line. In *Sinanthropus* H IV (d) and the almost adult *Sinanthropus* B V (e) the reconstructions of the arch were based on the preserved frontal part, so that both curves represent the actual conditions. It is evident that the general appearance of the arches of *Sinanthropus* H I, A II and H IV (textfig. 76 b-d) is about the same, while that of *Sinanthropus* G I (textfig. 76 a) differs from all three in size and width. Since the jaws H I, A II and H IV have to be considered as belonging to females according to their size and robustness and also according to the size of their teeth, and that of G I as belonging to a male individual (compare p. 17 & f), we are apparently dealing with a sex character. Apart from these differences the curve of the arches reveal the same particularity in all five specimens. As mentioned above (p. 37) in recent man the frontal part of the alveolar curve is more or less flattened so that it runs in almost a straight line from the canine of the one side to that of the other, thereby forming a distinct angle in the level of the canines with the latter acting as a kind of corner. In anthropoids this appearance is still more pronounced, with the canine angle projecting sharply in consequence of the tusk-like character of the canines. The outer contour of the alveolar arch therefore does not represent here a real curve but forms a rather rectangular figure. Textfigure 78 demonstrates such an appearance in the case of chimpanzee.

Sinanthropus G I differs in this respect from recent man as also from anthropoids in that the frontal part of the curve forms an evenly rounded off line (textfig. 76). This character is entirely independent from the special shape of the symphyseal part, that is to say, from the way of joining one half and the reconstruction of its mirror image. In *Sinanthropus* jaw G I the whole left side is preserved up to the first incisor, in *Sinanthropus* jaw A II the right side is almost intact up to the second incisors so that in both cases the original character of the frontal curve is observable. This will be evident when making a comparison with other alveolar arches by superposing the corresponding parts. For this purpose I used the Heidelberg jaw which is considered by most authors as representing the most primitive hominid type. In textfigure 77 a (p. 105) the *Sinanthropus* jaw G I is superposed directly upon the Heidelberg jaw, using as landmarks the contours of the masticatory surface of the teeth. The curvature of the *Sinanthropus* jaw clearly appears to be more V-shaped than that of the Heidelberg jaw, the latter showing a bending angle in the level of the canine. In textfigure 77 b and c (p. 105) the same procedure was followed in regard to *Sinanthropus* H I and A II jaws. In both of these drawings the Heidelberg jaw, which is thicker and longer than those of *Sinanthropus*, was reduced to conform to the size of the latter. The effect of superposition remains the same: the curve of *Sinanthropus* represents in itself a less curved line than that found in the Heidelberg jaw, regardless of the angle of juncture in which the two halves had been united.

In textfigures 78-88 (pp. 103-104) *Sinanthropus* is compared with chimpanzee, Neanderthal, and recent man by superposing the corresponding alveolar and basal arches. The point where the median line crosses the transveral line joining the "post-lacteons" of either side and the lines themselves were taken as the center of orientation. Textfigure 78 shows that the alveolar arch of chimpanzee is much shorter and narrower than that of *Sinanthropus* G I. The illustration in textfigure 80 reveals that in spite of having approximately the same width the arch of the male *Sinanthropus* jaw G I is considerably longer and more curved than that of the Heidelberg jaw. Compared with the female *Sinanthropus* jaw H I the Heidelberg jaw is wider, shorter and flattened, that is, it approaches closer to recent man than the *Sinanthropus* jaw. Among other jaws of the Neanderthal group the Krapina jaw G (textfig. 82) and Spy I jaw (textfig. 83) are clearly wider, shorter and less curved than *Sinanthropus*. Only the jaw belonging to the adult Ehringsdorf individual shows approximately the same general appearance as *Sinanthropus* G I, but the arch of the first mentioned is small as a whole. However, apart from this difference, the frontal part of the arch is flat compared with that of *Sinanthropus*, even if the design of the uncorrected alveolar arch given by H. Virchow (1920) is used as a basis. Among the jaws of recent man the prognathous mandible of a North Chinese male (textfig. 88), although smaller, approaches the *Sinanthropus* jaw G I. The Australian jaw (textfig. 87) is narrower and shorter than the *Sinanthropus* mandible, but nevertheless flatter.

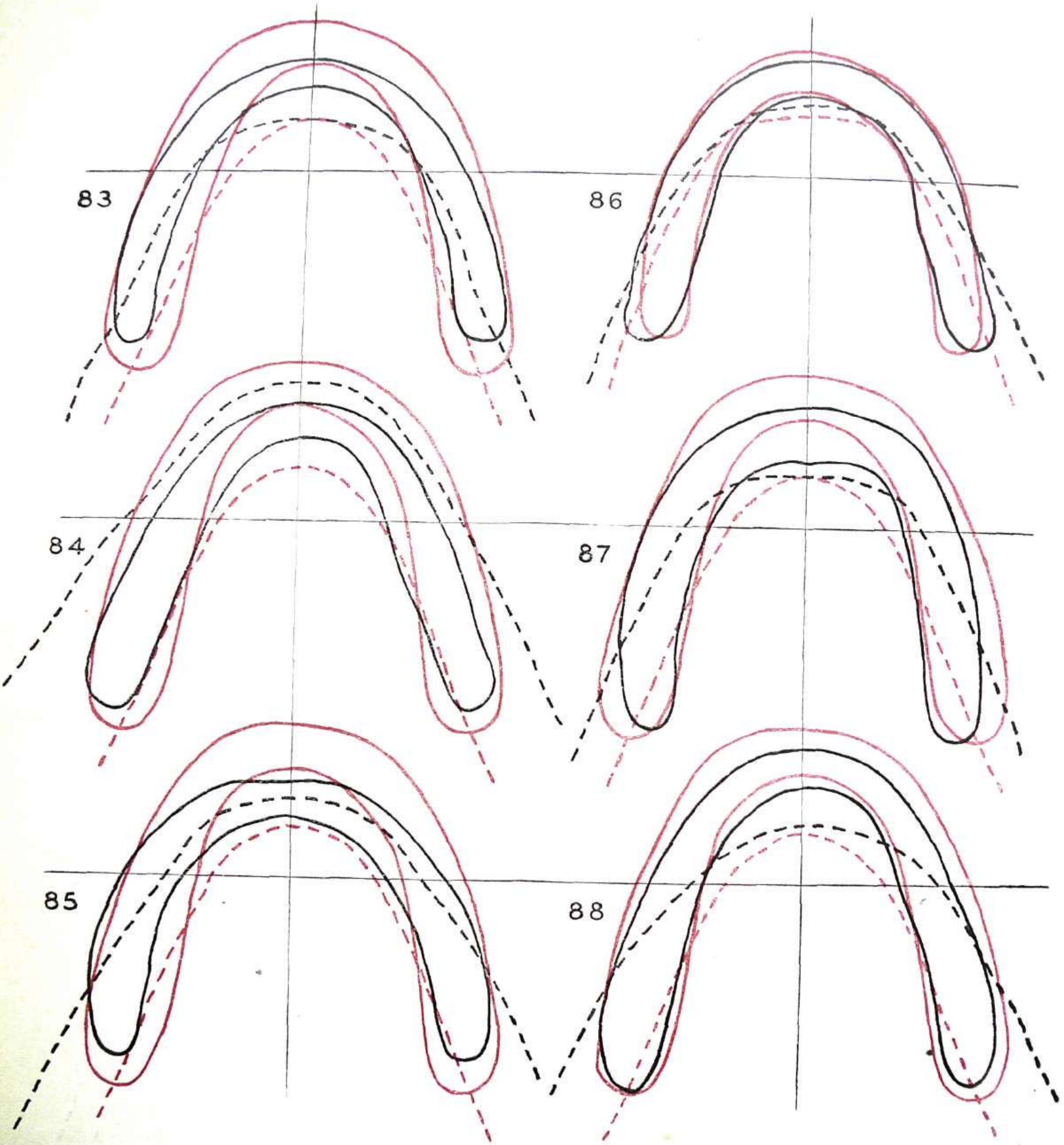
In textfigures 89-91 (p. 105) arches of the *Sinanthropus* jaw G I are compared with those of other *Sinanthropus* jaws using the same method of superposing. The illustrations show that the mandibular arch of the jaws H I

17 pag 105)



Figures 78-82. Alveolar and basal arches of the *Sinanthropus* mandibles in comparison with other mandibles in correct projection to the alveolar plane superposed in the cutting point of the middle line and "postlacteon" frontal line. The alveolar arch is represented by heavy lines, the basal arch by interrupted lines. *Sinanthropus* arches are in red throughout and comparative arches in black.

Figure 78 — male *Sinanthropus* G I and adult chimpanzee ♂.
79 — female *Sinanthropus* H I and Heidelberg.
80 — male *Sinanthropus* G I and Heidelberg.
81 — male *Sinanthropus* G I and Ehringsdorf adult.
82 — male *Sinanthropus* G I and Krapina G.



Figures 83-88. The same as in figs. 78-82.

Figure 83 — *Sinanthropus* G I and Spy I.
84 — *Sinanthropus* G I and Obercassel ♂.
85 — *Sinanthropus* G I and Choukoutien ♂ (101).
86 — *Sinanthropus* H I and Choukoutien ♀ (104).
87 — *Sinanthropus* G I and modern Australian native,
88 — *Sinanthropus* G I and modern prognathous North Chinese,

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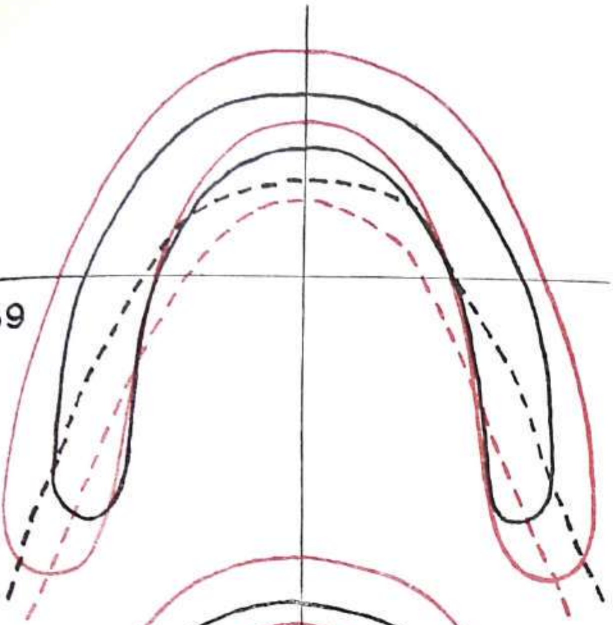

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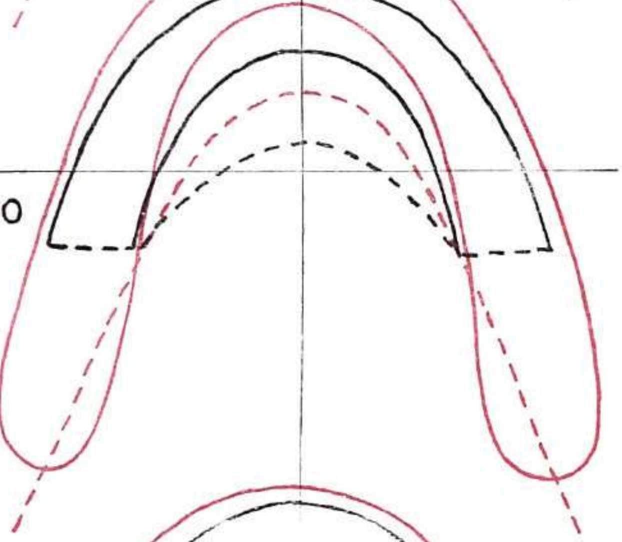

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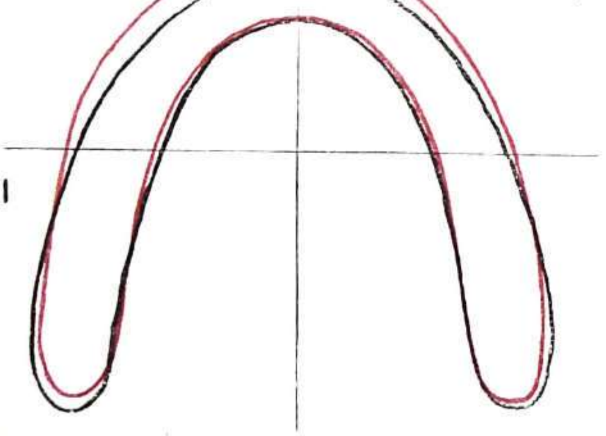

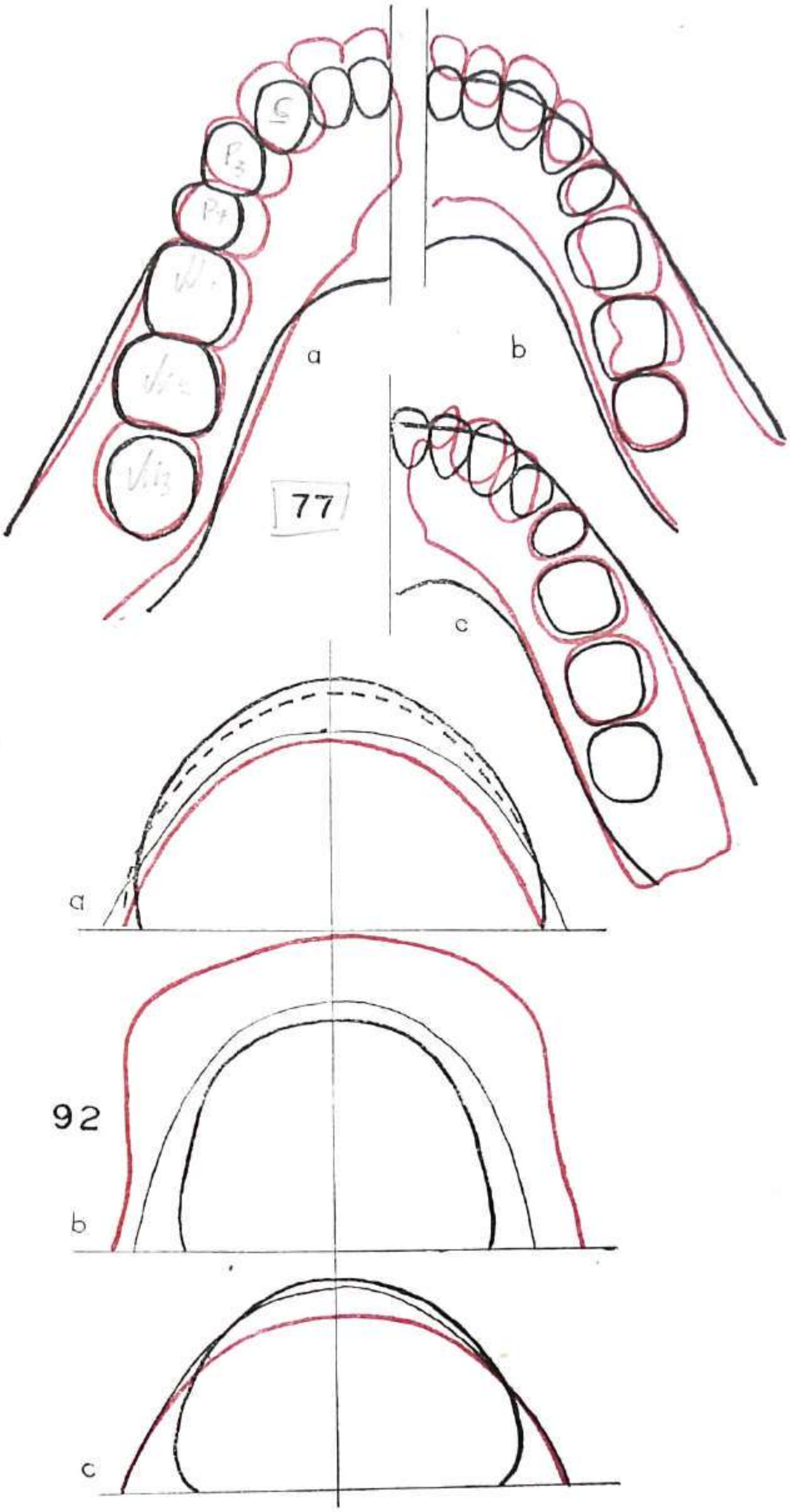

Figure 77. Outlines of the body and dental row of the *Sinanthropus* mandible and that of the Heidelberg superposed to demonstrate the difference in curvature of the dental row. The line in red: *Sinanthropus*, in black; Heidelberg. Designation: a, male *Sinanthropus* G I and Heidelberg; b, female *Sinanthropus* H I and Heidelberg; c, female *Sinanthropus* A II and Heidelberg. In *b* and *c* the Heidelberg mandible is reduced to the same size as the *Sinanthropus* mandibles.

Figures 89-91. The same as in figs. 78-82, with the exception that comparisons concern *Sinanthropus* mandibles only.

Figure 89 — *Sinanthropus* G I (red) and female *Sinanthropus* H I (black).

90 — *Sinanthropus* G I (red) and femal *Sinanthropus* H IV (black).

91 — Female *Sinanthropus* H I (red) and female *Sinanthropus* A II (black).

Figure 92. The outer contours of the alveolar arches of the different stages of dentition compared with the adult stage, and oriented in the alveolar plane and superposed in the cutting point of the middle line and "postlacteon" frontal line. Designations; — a, *Sinanthropus*: B IV ——, B V - - -, B I ——, H I (red); b, chimpanzee: adult (red), child with milk teeth ——, child with permanent incisors ——; c, recent man: North Chinese child with milk teeth ——, North Chinese child with permanent incisors ——, Prehistoric Chinese (Kansu) red.

and A II are almost identical (textfig. 91), and the same is true for H IV (textfig. 90) the arch of which differs to the same extent from jaw G I as jaw H I (textfig. 89), the latter being even smaller in all dimensions.

There remains another fact which deserves attention. In anthropoids the post-canine teeth are situated in a straight line, at times slightly bent inward in the level of M_2. In recent man they usually form a curve with a convexity in the level of the same tooth which is directed outward so that the cross-distance of the lateral surface of M_3 is smaller than that of M_2. Seldom can an inward bending of the curvature be observed as in anthropoids. *Sinanthropus* resembles recent man in this regard, the cross-distance of the lateral surfaces of M_3 being smaller than that of M_2.

In order to determine the course of the row of molars and thereby the degree of curvature of the dental and alveolar arch, Werth (1928) measured the angle formed by the longitudinal lines traced through the middle of the three molars on each side and prolongated to their anterior crossing point. According to Werth, the lines run parallel in anthropoids and catarrhines while they converge in recent man forming an angle varying from 20° to 40°. This convergence, according to Werth, is to remain unchanged regardless whether it concerns a primitive hominid or recent man, because he considers it to represent a very primitive character which man has in common with the prosimians, *Parapithecus*, *Pliopithecus*, etc.

It is not easy to decide on the correct measurement of the angle. St. Oppenheim (1926) recommended to fix two knitting needles on the row of molars with wax in such a way as to divide the molars into halves. It is much more convenient and more correct to take the measurements on the drawings in occlusal view, the mandible having been orientated in the alveolar plane. The measurements in the following table (Table XVI) were obtained with the latter method. However, the actual line of division of the molars is often very difficult to determine because, as stated above, the molars are seldom situated in a straight line, being usually arranged in more or less pronounced curve with an outward directed convexity. In anthropoids it may even occur that this convexity is directed inward. At times the third molar is small and does not fit into the row. In such cases it is wiser to exclude the third molar and to restrict the halving line to the first and second molar. Werth's suggestion had its origin in the supposition that the halving lines were parallel in anthropoids. However, this is not at all the case. In orang and chimpanzee the angle in question shows little

TABLE XVI.

Angle of molar rows of hominids arranged according to magnitude.

Australian	8°
Sinanthropus H I	13°
Wadjak II	18.5°
Spy I	22°
Sinanthropus A II	23°
Heidelberg	23°
Sinanthropus G I	24°
Predmost ♀	25°
Krapina H	28°
Choukoutien ♂	28°
Choukoutien ♀	28°
Ehringsdorf (adult)	29°
Chinese (prognathous)	32.5°
Eskimo	33°
Krapina I	35°
Chinese (Prehistoric)	35°
Obercassel ♀	39°
Obercassel ♂	42°

variation alternating from 2° to 5°; but in gorilla the fluctuation is greater amounting to 12°. In gibbons the angle exceeds in most cases the 20° mark. In hominids the angle varies from 8° to 42° as seen in the following table. Although Werth is correct in his assumption that a distinct gradual increase of the angle corresponding to the stage of evolution is not recognizable, with the type of the Neanderthal group interspersing in recent man, yet it is evident that *Sinanthropus* and the Australian occupy the lowest position within the entire order. I am therefore in doubt whether the conclusion drawn from the degree of the angle actually has the significance attributed to it.

All facts combined the alveolar arch of *Sinanthropus* reveals a prognathous form but in a much more moderate degree than is found in anthropoids. It resembles in this respect the form existing in recent man but with this difference that in the latter the male type corresponds to the female type of *Sinanthropus*.

b. Basal arch: The basal arch compared with the outer contour of the alveolar arch shows a different feature in anthropoids on the one hand and in recent man on the other. In chimpanzee, for instance (textfig. 78), the basal arch falls considerably behind the outer line of the alveolar arch, whereas in recent man (textfig. 84, Obercassel) it is located a good distance before this line. This difference is apparently due to prognathism, for the characteristic of this appearance is the projection of the alveolar process beyond the basal margin of the jaw. For this reason the same feature is observed to occur in recent man in all cases with prognathous jaws as illustrated in textfigures 87 (Australian) and 88 (North Chinese).

In *Sinanthropus* jaws, in male (G I) as well as in female (H I and H IV) the basal arch falls considerably behind the alveolar arch, especially behind its outer contour (textfig. 76, a, b, d), a condition which corresponds to the strong inclination of the frontal part of the mandibles (compare p. 78 & ff).

As is seen in textfigures 78-89 the curvature of the basal arch corresponds rather closely to that of the mandibular arch. In the instance of the mandibular arch forming a wide curve the basal arch will be wide also, and the same is true for the narrow curves. The Heidelberg jaw in comparison with *Sinanthropus* jaw H I (textfig. 79) is of special interest in this regard. The basal arch of the first evidently falls further back than that of the latter, but it is much more rounded. This greater widening can also be observed when comparing the Heidelberg jaw with *Sinanthropus* jaw G I. Furthermore, the anterior parts of the basal arch of the jaws of Ehringsdorf (adult), of Krapina G and Spy I are wider than that of *Sinanthropus* jaw G I, (textfigs. 81,83), the latter coinciding with chimpanzee (textfig. 78).

The length-breadth index of the basal arch cannot be compared directly with the same index of the alveolar arch. It is true that the differences in breadth are not important but the length differs considerably. The sequence in the following table is arranged according to the size of the index.

TABLE XVII

Length-breadth index of the basal arch (compare Table XV)

Gorilla	82.0
Orang	79.4
Sinanthropus G I	68.2
Ehringsdorf (adult)	67.6
Sinanthropus H I	62.7
Predmost ♂	62.7
Krapina G	60.8
Chimpanzee	59.8
Spy I	56.9
Heidelberg	56.7

It is evident from this table that the index does not have a great comparative value, yet it demonstrates that in this respect also *Sinanthropus* approaches the anthropoids more than the Neanderthal group, with the exception of the Ehringsdorf adult.

c. The anterior alveolar arch: As discussed in detail in my publication on the origin of the chin (1934), there exists a fundamental difference between anthropoids and recent man in regard to the conditions of development of the mandible during dentition. When the first permanent molar makes its appearance, it represents a characteristic mark of growth. All the other molars erupting after it cause a lengthening of the mandible in a posterior direction. This takes place in anthropoids as well as in recent man. However, the course taken on the alveolar arch by the replacing dentition before the first permanent molar is entirely different in anthropoids and man. The permanent teeth of anthropoids, especially the canines, are much larger and longer than the deciduous teeth which they are replacing. Therefore, the available space in the mandible first occupied by the milk teeth becomes inadequate for the permanent teeth, and the mandible develops forward to a very large extent.

In textfigure 92 b the extent of such an increase in length is marked by the outlines of the alveolar arch of a chimpanzee child with complete milk teeth on the one hand, and of an adult male chimpanzee on the other. The transversal line represents the posterior boundary of this anterior alveolar arch uniting Bolk's "postlacteons" (see above). Recent man presents quite a different condition (textfig. 92 c). Here the milk teeth occupy a space which is not smaller than that taken by the replacing permanent teeth but on the contrary even larger. This is especially true in the case of the two premolars which are much shorter than the two milk molars. The space occupied by the milk incisors and milk canines is slightly smaller than that occupied by the corresponding permanent teeth. However, the difference in length of milk molars compared to that of premolars is so great that the space is not only sufficient to cover the small deficiency but there remains a surplus in length which is compensated by an actual shortening of the alveolar part, in other words the frontal part of the alveolar process undergoes a slight retraction.

This is the reason why the anterior alveolar arch of juvenile recent man with the milk teeth is longer than that of an adult with the permanent teeth, but on the other hand, the arch of the latter is wider. The transformation of the arch during dentition can best be illustrated by a comparison of the juvenile arch with a Gothic arch and that of an adult with a Roman arch. In textfigure 93 the arches are superposed upon each other in the line uniting the postlacteons of each side. The average shortening amounts to about 4 mm, which means that the length of the arch is shortened by about 18.5%.

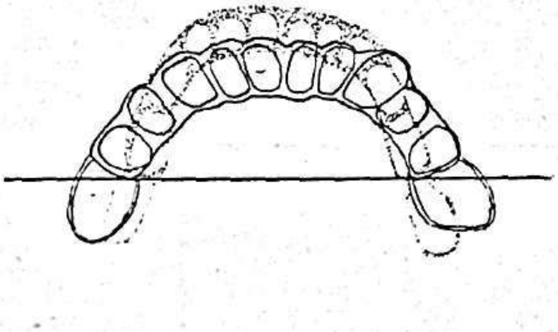

Figure 93. Anterior alveolar arches of a mandible of recent man with the set of milk teeth (stippled field) and those of an adult recent man superposed in the "postlacteon" frontal line.

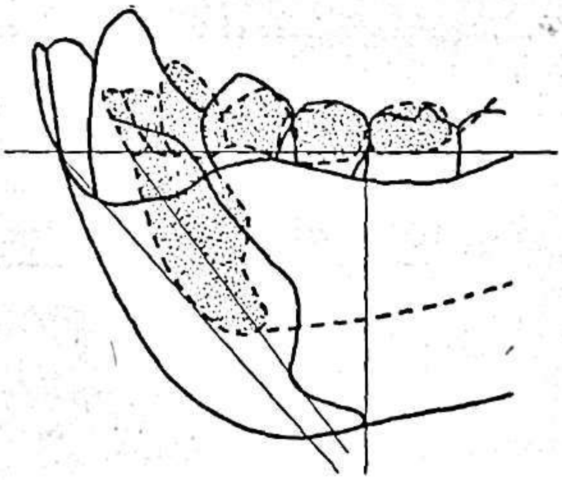

Figure 94. Diagrams in profile views of the mandible of a chimpanzee child with milk teeth (stippled field and interrupted lines) and that of an adult chimpanzee (full line) superposed in the alveolar plane and "postlacteon" perpendicular. Natural size.

In textfig. 94 the profiles of the mandibles of a female chimpanzee child with a complete set of milk teeth and of an adult female chimpanzee are superposed in the alveolar plane and at the same time in a line perpendicular to this plane and erected at the "postlacteon." From the illustration it is evident that the mandible grows directly forward during dention. In male individuals and in gorilla, orang or baboons where the differences in size of the teeth, especially of the canines and the first premolars, are still more pronounced, the extent of this forward development is more striking. Textfigure 95 c demonstrates the same phenomenon in recent man. Here I chose a North Chinese child with a complete set of milk teeth and a strongly prognathous adult North Chinese male. Inspite of the prognathism of the latter his alveolar arch is considerably shorter than that of the child.

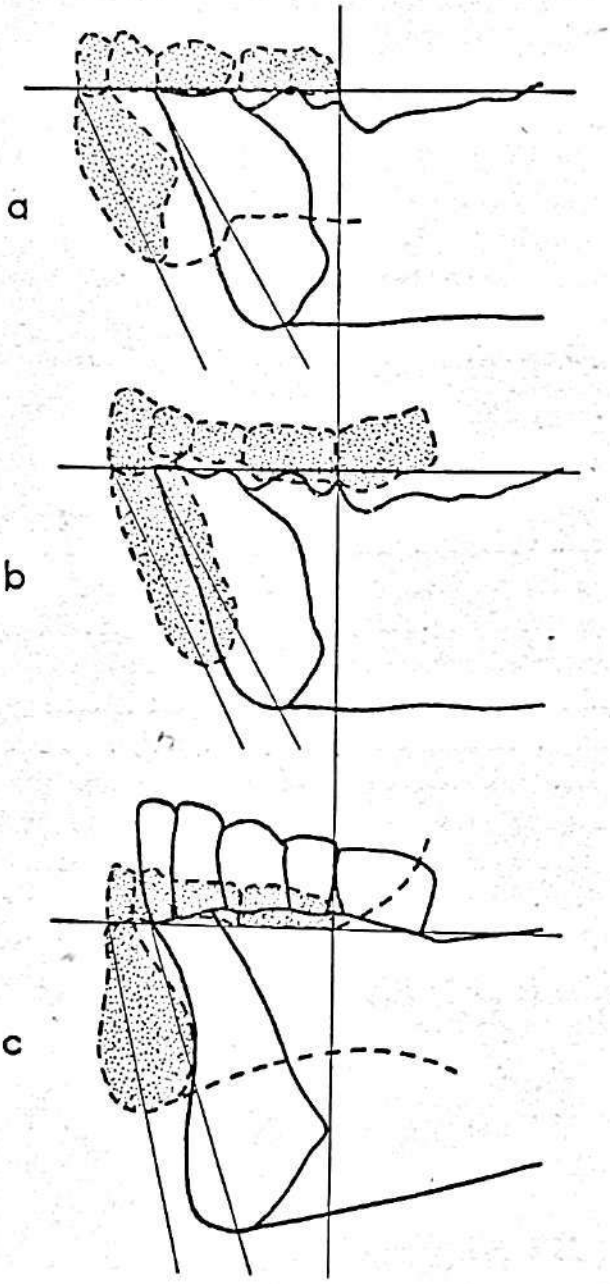

Figure 95. The same as in fig. 94 of *Sinanthropus* and recent men respectively. Designations:— a, *Sinanthropus* child B IV (stippled field and interrupted lines) and female adult *Sinanthropus* H I (full lines). b, *Sinanthropus* child B I (stippled field and interrupted lines) and female adult *Sinanthropus* H I (full lines). c, modern North Chinese child with milk teeth (stippled field and interrupted lines) and modern North Chinese adult (full lines). Natural size.

I consider the differences described as existing between anthropoids and recent man as of great importance because we are dealing, I believe, with fundamental differences which may throw a great deal of light on the question as to how large the canines of the direct forerunner of hominids may have been. Among all Catarrhina only the Semnopithecinæ show about the same appearance as recent man with regard to the manner of transformation of the anterior alveolar arch. As evident from textfigure 96, in Presbytes the arch is stationary, that is, its length is about the same in the juvenile and adult stage.

Under these circumstances it is of special interest to know how *Sinanthropus* is in this respect. In textfigure 95 a I combined the profile of the *Sinanthropus* mandible B IV representing a jaw with a complete set of milk teeth with that of the adult *Sinanthropus* jaw H I in the same orientation as described above. It is evident that *Sinanthropus* displays the same feature as recent man, the anterior alveolar arch of the juvenile stage being much longer than that of the adult. As textfigure 95 b reveals, there is no great difference in the *Sinanthropus* jaw after the milk incisors have been replaced by the permanent teeth. The jaw used in this comparison is that of *Sinanthropus* B I, in which the permanent incisors have completely erupted while the milk canine and milk molars are still in their respective sockets. Thus it becomes evident that the actual shortening of the arch takes place only when these latter teeth have been replaced.

Neanderthal man exhibits the same character as *Sinanthropus* and recent man. In textfigure 97 there is combined the profile view of the jaw of the Gibraltar child, which corresponds to the stage of dentition of *Sinanthropus* B IV, with the profile of the uncorrected jaw outline of the Ehringsdorf adult. Although the latter mandible is extraordinarily prognathous, the shortening of the anterior alveolar arch is very strongly pronounced.

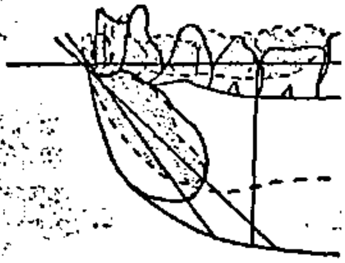

Figure 96. The same as in fig. 94. *Presbytis entellus* child with milk teeth and adult specimen. Natural size.

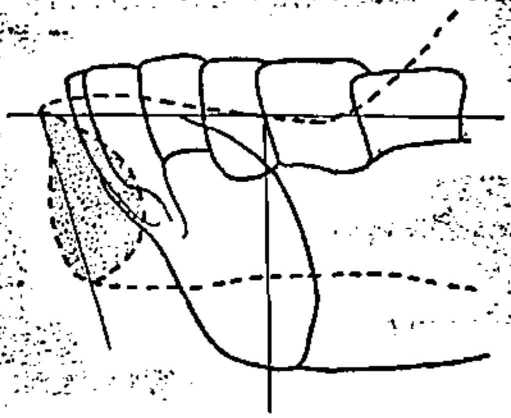

Figure 97. The same as in fig. 94. Neanderthal man: Gibraltar child (stippled field and interrupted lines) and Ehringsdorf adult (full lines).

Textfigure 98 demonstrates the appearance of the first stage of dentition in chimpanzee child, *Sinanthropus* child B IV, Gibraltar child and recent Chinese child and illustrates the anterior alveolar arches viewed in the alveolar plane. It should be noted that the arch of *Sinanthropus* is much wider than that of the Gibraltar child and recent Chinese, the Gibraltar child again having a wider arch than the latter. Textfigure 99 demonstrates the same but refers to the more advanced stage of dentition with the permanent incisors already erupted. Textfigure 92 shows the position and form of the anterior alveolar arch which is represented by its outer contour in three stages of dentition (first, second and adult) for chimpanzee, *Sinanthropus* and recent Chinese and viewed in the alveolar plane, the red lines indicating the adult stages. In *Sinanthropus* (textfig. 92 a) the stage of jaw B IV, in which the first premolar already occupies its definite position, is also indicated. Of course, it cannot be expected that the various lines absolutely correspond to each other, since they do not represent the different stages of dentition of the same individual but belong to several individuals with probably some differences in the shape of their alveolar arches. Thus, computations derived therefrom can only be considered as standard examples of the general character of the transformation in question. The same applies to all the computations in relation with this process.

In Table XV measurements of the anterior alveolar arches of the juvenile and adult stages are listed. For *Sinanthropus* the following measurements were obtained.

	length	breadth
Sinanthropus child B IV	32.5 mm	46.0 mm
Sinanthropus adult G I	28.0 mm	47.0 mm
Sinanthropus adult H I	23.5 mm	47.0 mm
Gibraltar child	27.5 mm	46.0 mm
Ehringsdorf adult	23.0 mm	45.0 mm
Chinese child	26.0 mm	37.0 mm
Chinese adult (prognathous)	23.0 mm	44.0 mm
Chimpanzee child	29.0 mm	33.0 mm
Chimpanzee adult	39.0 mm	49.0 mm

From these figures it becomes evident that the anterior alveolar arch in recent man is widened considerably during the process of shortening. Neither in *Sinanthropus* nor in Neanderthal man does such a widening occur, the

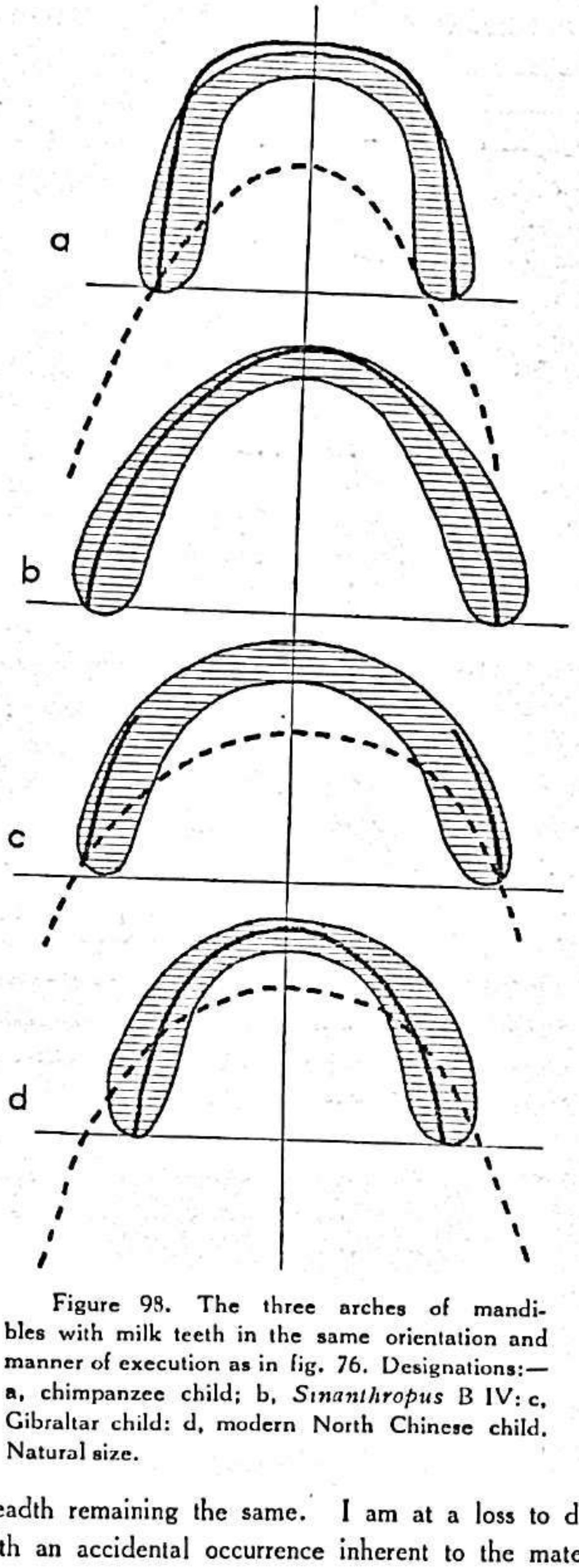

Figure 98. The three arches of mandibles with milk teeth in the same orientation and manner of execution as in fig. 76. Designations:— a, chimpanzee child; b, *Sinanthropus* B IV: c, Gibraltar child: d, modern North Chinese child. Natural size.

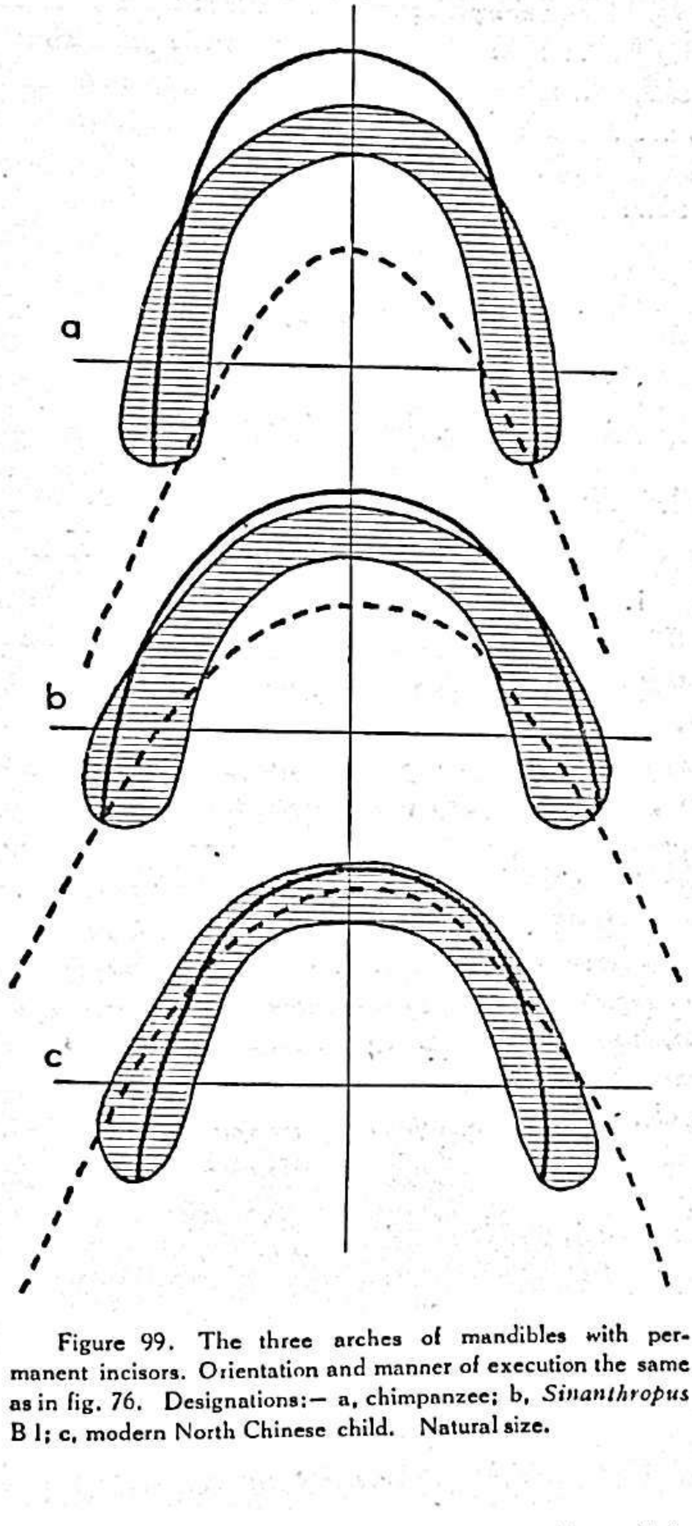

Figure 99. The three arches of mandibles with permanent incisors. Orientation and manner of execution the same as in fig. 76. Designations:— a, chimpanzee; b, *Sinanthropus* B I; c, modern North Chinese child. Natural size.

breadth remaining the same. I am at a loss to decide as to whether we are dealing with a general peculiarity or with an accidental occurrence inherent to the material at our disposal.

As another reason for the shortening of the anterior alveolar arch I gave the difference in length between the two milk molars and the two premolars occupying their positions during dentition. In recent man the former are longer than the latter. The same is true for *Sinanthropus*. In both cases in which the milk molars are preserved in their respective sockets (B III and B IV, Plate VIII, figs. 3 a and 8) their length is 22.3 mm, or including the gap between the canine and the first milk molar as in the case of B IV 25.4 mm. In the adult *Sinanthropus* jaw H I the area occupied by the two premolars is only 14.6 mm and in *Sinanthropus* jaw A II 13.2 mm. In recent man the averages in question amount to 14.4 mm for the milk molars and 11.4 mm for the premolars. It is true that in *Sinanthropus* G I the length of the premolars is considerably more, amounting to 22.3 mm. Nevertheless the *differences* between the two groups of teeth are much greater in anthropoids as is seen from the following table:

	Milk molars	Premolars
Gorilla	22.4 mm	32.0 mm
Orang	16.1 mm	25.5 mm
Chimpanzee	10.7 mm	16.0 mm

Sin. 22,3 13,9 (m.
Hp. 14,4 11,4 (m

I shall deal more in detail with this question in my publication on the teeth of *Sinanthropus* which is to appear in the near future.

VI. THE PECULIARITIES OF THE *SINANTHROPUS* MANDIBLE AND ITS COMPARISON WITH OTHER HOMINID MANDIBLES

1. The sexual difference. When observing the two best preserved mandibles of *Sinanthropus* G I and H I (Plate XI-XV, figs. 1 and 2), one gains the impression that great differences exist between the two specimens, so that it may be difficult to find the leading peculiarities characterizing this hominid. The size of jaw G I in particular is most striking and when compared with the small jaw H I it appears to be of quite a different type. However, a more careful study reveals that this small type represented by *Sinanthropus* jaw H I is also met in the jaws A II and H IV, thus delineating a distinctive group among the mandibles of *Sinanthropus*. The badly worn teeth of all three jaws A II, H I and H IV prove that they belong to old, adult individuals. The small size of the teeth corresponds also to that of the respective mandibles and stands in contrast to the large size of the teeth in jaw G I.

I believe, that this large jaw G I represents an adult male individual and the three small jaws A II, H I and H IV adult females. As far as we know, sexual differences in mandibles of recent man are only manifest *in size, but unfortunately no special investigation on this problem has ever been carried out.** R. Martin (1928) confines himself to the statement that the measurements of female mandibles are absolutely smaller throughout than those of male jaws. Other authors consider it self-evident that lowness and smallness of the mandible are indications of its belonging to the female sex, as for instance Hrdlicka (1930). According to Adams (1917) the mandibles of the Alsatian women are smaller in all dimensions than those of men. The ratio of the average of six measurements is 90:100. Schreiner (1935) gives some average figures of male and female mandibles of Lapps as follows:

	Male	Female	Index
Bigonial breadth	103.9 mm	95.3 mm	91.7
Bicondylar breadth	121.2 mm	114.8 mm	94.3
Bimental breadth	45.2 mm	43.4 mm	95.8
Height of the symphysis	31.7 mm	28.8 mm	90.8
Height of the ramus	57.8 mm	51.8 mm	89.5
Breadth of the ramus	33.9 mm	31.6 mm	93.3
Angle of the mandible	122.6°	125.2°	102.2

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* The references given by Morant in his most recent publication (1936) came to my attention too late to be included here. In any case, as emphasized by Morant himself, the biometric method which he and his collaborators devised does not provide sufficient certainty of determination of the sex on the basis of measurements alone. The fact that height, breadth of the ramus, mandibular angle and height of the body depend on sex has also been shown in preceding pages.

Shima (1933) likewise distinguished between male and female in his investigations carried out on Chinese, Koreans and Japanese. The following average figures for the three groups combined were derived from his lists:

	Male	Female	Index
Bigonial breadth	101.1 mm	94.5 mm	93.6
Bicondylar breadth	121.4 mm	115.4 mm	95.1
Bimental breadth	47.0 mm	45.4 mm	96.6
Height of the symphysis	34.6 mm	31.2 mm	90.4
Height of the ramus	62.8 mm	55.9 mm	89.0
Breadth of the ramus	34.2 mm	32.1 mm	93.8
Angle of the mandible	122.8°	128.1°	104.4
Length of the mandible	104.4 mm	99.4 mm	95.0

The corresponding measurements for *Sinanthropus* are as follows:

	Male (G I)	Female (H I)	Index
Bigonial breadth	108.6 mm	97.8 mm	90.0
Bicondylar breadth	146.4 mm	101.8 mm	69.5
Bimental breadth	46.1 mm	53.6 mm	116.4
Height of the symphysis	40.0 mm	31.4 mm	78.5
Height of the ramus	66.7 mm	59.0 mm	88.5
Breadth of the ramus	40.7 mm	39.7 mm	97.6
Angle of the mandible	97.0°	108.0°	111.2
Length of the mandible	103.0 mm	94.0 mm	91.2

The indices given above indicate the percentage of size of the special measurements in females compared with those of males.

In connection with the above measurements it should be noted that the bimental breadth — the direct distance of the mental foramina — is difficult to determine in *Sinanthropus* on account of the multiplicity of the foramina. I therefore chose the distance of the approximate center of the area concerned (compare p. 28). It is strange that this distance is much greater in the small specimen than in the large one. As to the measurement of the length of the mandible the incision is taken as the foremost point.

The indices derived for the Mongolian population of today listed in the tables above show that only a very insignificant difference exists between them. Taking all comparable dimensions together, with the exception of the bimental breadth, the female size is approximately 92.4% of the male. In *Sinanthropus* this relation amounts to only 85.9%. As to the mandibular angle it is about 4° steeper in the male than in the female, the total difference being 11° in *Sinanthropus*. Although we deal with average figures in the case of recent man and only with two individuals of *Sinanthropus*, I have the impression that the sexual differences are more pronounced in *Sinanthropus* than in recent man. I arrived at this conclusion because the two other small specimens of *Sinanthropus* at our disposal (A II and H IV) correspond in all available measurements to jaw H I, so that the latter mandible may be considered to present almost a standard *Sinanthropus* female.

The ratio in question between male and female amounts to 78% in orang, and 80% in gorilla. Unfortunately, I was unable to determine a correct ratio for chimpanzee due to the lack of suitable material. As much as I could determine in the latter, I found the ratio to be about 87%. These figures demonstrate that the sexual differences in *Sinanthropus* with regard to the size of the mandible are about of the same extent as those observed in the chimpanzee and much greater than those in recent man.

Of course, it is difficult to say whether differences in size which are so obvious are really due to sex just because of lack of any other reliable confirmation. However, as I pointed out earlier (1935), the same differences can be recognized in regard to the teeth, and, as new findings (Weidenreich, 1937) demonstrate, also to a certain extent in regard to the skull. Thus, it is evident that we are dealing with two types of *Sinanthropus*, a large and a small one. Parenthetically I may say that there is no doubt that both types belong to the same hominid, *Sinanthropus*, as will be proven as far as the mandibles are concerned in the pages to follow. I fail to see any other factor which could be made responsible for the differences in question. The idea that there may have been two races, a large and a small one, living in the Choukoutien cave may be discarded. The list of the *Sinanthropus* population given in my earlier publication (1935) reveals for instance that in Locus B mandibles of four children ranging in age from 5 to 11 years were recovered, two of which belong to the large and two to the small type. From Locus C we have two children, one belonging to the large and one to the small type. It seems rather improbable that two different races lived in the same cave and under the same cultural conditions, intermingling with each other. Furthermore, all jaws show the same degree of damage which I considered an indication of cannibalism (1935) or at least of deliberate crushing by man, and all individuals have been victims of such treatment, regardless of type. On the other hand, if all large jaws recovered are to be considered as belonging to a large race and all small ones to a small race, which of the specimens are then to represent the male and female sex both of which will have been present in the cave? Taking all these facts into consideration, there remains no other possibility than to attribute the large jaws to males and the small ones to female individuals. If this is correct, the differences in size due to sex are much more pronounced in *Sinanthropus* than in recent man and approach those occurring in anthropoids, especially in chimpanzee.

2. The main characteristics of the mandible. The mandible of the male *Sinanthropus* as a whole is much larger and bulkier than that of recent man. This does not hold good to the same extent for the female, although the ramus exceeds considerably in hight and breadth the average for Mongols of today. The index of robustness is indeed a reliable indicator of the differences occurring in this respect. As shown above (p. 86) this index of 59.4 for *Sinanthropus* jaw A II and of 58.4 for jaw H I exceeds by far that of recent man whose average index amounts to only about 40.5 for both sexes together and to about 41.0 for males only. The same index for male *Sinanthropus* is 48.3, but as shown above this difference is a consequence of the different in height, the male having a higher body than the female. Compared with Mongolian recent man the male *Sinanthropus* exceeds the average index of the latter by about 10 units (48.3 to 38.9)*.

As to the height of the body the male *Sinanthropus* with a symphysis height of 40 mm reaches the upper margin of recent man. However, it should be noted in this connection that the respective measurements do not conform exactly on account of the fundamental differences existing between the alveolar and basal part of the symphysis described earlier in this publication (p. 84 f), where it is shown that the *Sinanthropus* jaw is equipped with a higer alveolar and a lower basal part than recent man. This difference becomes apparent when measuring the height of the foramen supraspinosum over the lower margin as base. While in recent man this foramen is situated only slightly below the middle of the whole height of the symphysis (index 47.5), in *Sinanthropus* it

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* It is impossible to compare the measurements of *Sinanthropus* given above with those of others before having ascertained their methods. For instance, the height of the ramus of the male *Sinanthropus* measured with the usual method is 66.7 mm. Schulz (1933) choosing another gonion found the maximum of this measurement in recent Formosian to be 73.0 mm. However, with the method applied by Schulz the height of the ramus of the male *Sinanthropus* would be 80.8 mm and of the female 72.5 mm.

is located slightly below the lower third of the height (index 30.2), with the anthropoids representing a still lower rate in this regard (index 16 to 28).

The breadth of the mandible deserves special attention. The bicondylar breadth of the male *Sinanthropus* amounts to 146.4 mm which is in excess of the maximum (140.0) measurements in Eskimos (Fürst and Hansen) taken for comparison because of their exceptional wide jaws. The bigonial breadth of the former is, it is true, remarkably below the latter's maximum (108.6 to 130.0). In both measurements the female jaws fall within the range of variation of recent man.

As to the angle of inclination of the frontal part the adult *Sinanthropus* with approximately an angle of 60° (59° and 60.5°) has the lowest angle known hitherto among hominids, with the exception of the Heidelberg jaw (60.5) which has about the same inclination. In anthropoids the inclination is still stronger excepting Symphalangus which sometimes may reach the same degree. It seems that another angle, namely the mandibular angle, may be connected with it in some way, the mandibular angle in *Sinanthropus* amounting to 97° (♂) and 108° (♀) respectively. This degree contrasts considerably to those of recent man with an average of about 125°. *Sinanthropus* equals gorilla and orang in this character. Another striking phenomenon is the parallelism between the alveolar and basal planes which is evident in *Sinanthropus* jaws and which is also found in gorilla and orang.

The shape of the alveolar arch presents a very characteristic picture in all available adult specimens. Compared with recent man the *Sinanthropus* arcade represents a horseshoe-shaped, long and relatively narrow curve with its frontal part equally rounded in the region of the canines and incisors and not flattened or retracted as in the case of recent man. Corresponding to the forward inclination of the frontal part of the mandible the arcade projects considerably in the same direction. Inspite of the widely set rami of the male *Sinanthropus* jaw G I the free ends of the arches come close to each other. The length-breadth index of the alveolar arch amounting to about 100 and more is high but when considered alone, it does not signify much on account of the prognathous mandibles or recent man which also attain the 100 mark or which may even exceed the latter. This index is only of significance in connection with all the other features of the alveolar process of the mandible such as the angle of inclination, the absence of the incurvatio mandibulæ anterior and the mentum osseum respectively, the largeness of the area of the roots of the frontal teeth and the special shape of the frontal part of the dental or alveolar arcade.

In regard to the peculiarities of the relief of the surfaces one of the most outstanding facts is the absence of a mentum osseum combined with a clear indication of beginning formation of a mental trigonum represented by a faint tuber symphyseos. The incurvatio mandibulæ anterior is slightly defined in jaw H I. In *Sinanthropus* jaw G I the area of the roots of the frontal teeth occupies a much larger space than is to be observed in any other hominid known hitherto, including the Heidelberg jaw. This feature together with the strong inclination of the frontal part points to a very primitive stage. Nevertheless that a mental trigonum dawns is in conformity with the appearance of the inner surface at the frontal part. It is surprising at first glance that a planum alveolare or a torus transversus superior, so strongly developed in the Ehringsdorf and Heidelberg jaws, is almost completely absent in all of the *Sinanthropus* jaws (G I, H I, H IV B I, B V). The same is true for the fossa genioglossi in so far as the adult specimens are concerned. Instead of this pit, there is a real mental spine consisting of one upper pair of tubercles for the attachment of the genioglossi and a lower pair fused to a single one for the attachment of the geniohyoidei. It is true that the area of the whole spine is small and is far from attaining the extent occupied by it in recent man, but there exists a real and distinct spine which has never been observed before in such a characteristic appearance in any of the Neanderthal mandibles, with the exception of the jaw of La Chapelle-aux-Saints. On the other hand the region of the gnathion and lower border reveals a truly primitive character. The symphysis projects downward like a crest in the form of a small triangular prominence separating the digastric fossæ from each other and dividing at the same time the incisura submentalis. The digastric fossæ are long and narrow and are located in their entire extent immediately at the lower border of the jaw as in chimpanzee and gorilla and do not overlap to the vertical inner surface as in Neanderthal and recent man. Of the other parts of the body the strong formation of the torus marginalis is remarkable. In connection with this the tuberculum marginale anterius is well developed and thereby also the incisura submentalis. The fact that these latter features are defined more distinct in the female jaw H 1 and to a certain extent also in A II than in the male jaw G I depends upon the greater and more uniform bulkiness of the latter.

It is strange that a multiplicity of the mental foramen is characteristic for *Sinanthropus*. In all specimens on hand, adult and juvenile, in which this region is preserved, more than two foramina are present. The adult jaw G I has five foramina, A I four and H I three foramina. This appearance is exceptional for hominids (for Neanderthal man as well as recent man) and even also for anthropoids. Three foramina occur very seldom in man and four have never been found hitherto.

Another peculiarity of the inner surface of the body is the torus mandibularis in the form of the striation and tubercle type. Since this phenomenon has been discussed in great detail earlier in this publication, it is sufficient here to refer the reader to that particular section.

As to the peculiar appearance of the ramus, I have already mentioned its steepness and its largeness, especially its remarkable breadth in the female *Sinanthropus* jaw H I. In all specimens of the adult as well as of the juvenile individuals the whole region of the angle projects backward and at the same time everts rather strongly, forming in this way a deep and large fossa masseterica. The site of the angle itself is slightly blunted. The lateral and medial surfaces of the ramus present some remarkable features. The crista ectocondyloidea is still more marked in the female jaw H I than in the male jaw G I, it begins below the condyle with a very pronounced tuberculum subcondyloideum laterale. In jaw H I there is also a well developed crista endocondyloidea. The torus triangularis, the prominence on the medial surface of the root of the coronoid process (see p. 68) gives rise to a crista pharyngea. The region behind the foramen mandibulare attracts attention through the formation of the strong muscle markings for the attachment of the two pterygoidei, the tuberculum pterygoideum inferius apparently being destined for a strong portion of the pterygoideus internus and the tuberculum pterygoideum superius for the pterygoideus externus. Both tubercula are separated by a clearly developed furrow — sulcus colli — coursing from the border of the ramus to the mandibular foramen. Both muscle markings characterize the male jaw of *Sinanthropus*, and are already well developed in the juvenile jaws, while the lower tubercle is almost completely absent in the female jaw H I.

The coronoid process is broad and thick and its anterior border forms an angular projection so that the top of the process falls slightly backward. The condyloid process varies and as a whole is directed inward and the medial part of its articular surface slopes steeply in the same direction. Below its lateral corner there is a distinct tuberculum subcondyloideum externum for the attachment of the ligamentum tempero-mandibulare. In the female jaw this relief is less developed. The incisura semilunaris is neither strikingly flat nor particularly deep, its deepest point being located approximately in the middle or nearer to the condyle process.

The juvenile mandibles reveal the same character as the adult jaws with regard to their general bulkiness, even when the sexual differences are considered in this connection, which begin to become apparent in the juvenile stages, in correspondence with the differences in the size of the teeth. The strong inclination of the frontal part, the absence of the mentum osseum, the faint indication of a mental trigonum and the horizontal position of the digastric fossæ can be clearly observed in *Sinanthropus* jaw B I. This jaw is especially remarkable for a slight fossa genioglossi combined with the early formation of the mental spine. In addition a kind of planum alveolare is to be recognized here but only as a very weak eminence. Compared with the adult the angle of inclination is slightly less acute (63° and 65° to about 60°), and the angle of the ramus which is 107° to 112° is less steep than in the adult in conformity with the condition existent in juvenile recent man where at a corresponding age the angle rises to 121-131°. Other peculiarities pertaining to the juvenile jaws have been dealt with in the immediately preceding chapter. As to the anterior alveolar arch, the only one concerned, it is much longer and more widely stretched than in recent man and essentially longer than in the adult *Sinanthropus*. A distinct shortening takes place during dentition in which *Sinanthropus* apparently follows the human line and differs fundamentally from the anthropoids.

3. A comparison with other hominid jaws. Although, as indicated by the title, this chapter concerns hominid jaws, I cannot refrain from referring briefly to *Australopithecus africanus*. Since it is my intention to discuss this fossil in my following publication on the *Sinanthropus* teeth, I shall confine myself here to a few words. I agree completely with Dart (1926) and Broom (1933) that *Australopithecus africanus* is neither a gorilla nor a chimpanzee when compared with the specimens of today and my interpretation concurs with that of the two authors in that Australopithecus somehow belongs within the line of human evolution. This is essentially but not exclusively proven by the appearance of the teeth. In my Japanese lecture (1936) I called attention to one of the peculiarities observed in the first upper molar. There can be no doubt that the teeth of *Australopithecus* approach those of *Sinanthropus* more than those of chimpanzee or gorilla.

With reference to the mandible a reliable comparison is difficult because the major part of the *Australopithecus* jaw is missing, and unfortunately the same is true for the corresponding parts of *Sinanthropus* jaw B IV which is exactly of the same age as the former. However, certain facts are recognizable. The mandibular arches of the *Australopithecus* mandible are undoubtedly narrower than those of *Sinanthropus*. A well developed planum alveolare (torus transversus superior) exists in the former and below it a fossa genioglossi. This is in contrast to *Sinanthropus*, it is true, but as was shown above, *Sinanthropus* occupies a special position in this respect. On the other hand the preserved ramus of *Australopithecus* reveals that there are great differences between its ramus and those of gorilla and chimpanzee, and at the same time a close resemblance to the juvenile *Sinanthropus* jaws B I and F I is visible.

Among the mandibles of real hominids or at least those attributed to them, two are of essential importance because of their rivalry with *Sinanthropus* for geological antiquity. These are the mandibles of Piltdown and Heidelberg.

The Piltdown mandible. I do not intend to discuss here the problem bearing on the definition of *Eoanthropus Dawsoni*, for I have already explained my interpretation of this form in a preface to the publication by my pupil Friederichs (1932). In the meantime I have been given the opportunity to study the original findings and this has only strengthened my reservation and scepticism in spite of more recently expressed opinions to the contrary. In connection with the mandibles of *Sinanthropus*, there is only one factor to be debated, namely the morphological character of the Piltdown jaw. It may be recalled that not less than four well known investigators in this particular field, namely Miller (1915), Gregory (1916), Ramström (1916) and Lenhossek (1920) completely refused to accept the hominid character of this fossil, and attributed it to an anthropoid. As this statement is based on purely morphological features of the mandible itself, it cannot be weakened or annulled by any consideration referring to the brain case which is presented as pertaining to the mandible, or to special finding circumstances. The matter is very simple. If the Piltdown mandible is to be considered as belonging to a human being, then there remains no other choice but to surmise that the forerunner of recent man was equipped with a real anthropoid jaw like that of chimpanzee. This would imply that in England a hominid lived with the brain case of recent man and an ape-like mandible, while in the Far East (Choukoutien) at about the same time another human being lived with the most primitive brain case known hitherto, approaching that of chimpanzee and with a mandible distinctly closer related to that of recent man than to chimpanzee.

As to the chimpanzee character of the Piltdown mandible Friederichs (1932) demonstrated that it approaches much more the jaw of a female orang than that of a chimpanzee. Among 53 characteristics of the mandible and molars 32 proved to be those belonging to a female orang, 7 to a chimpanzee, 4 to orang and chimpanzee, 4 to orang and recent man, 3 to orang, chimpanzee and recent man, 1 to chimpanzee and recent man, 2 to orang, Heidelberg jaw and recent man, and not one single one to recent man exclusively. This statement may render further particularization superfluous. Yet, we are dealing here with *Sinanthropus* and not with recent man, and therefore there remains the possibility of a closer relation between the two mandibles in question. However, this is not at all the case. The Piltdown jaw resembles at the most a female orang and is no more similar to *Sinanthropus* than the female orang. It is sufficient here to refer to two facts. In textfigure 50 I demonstrated that in *Sinanthropus* there is present a large and long digastric fossa located directly at the lower surface on either side of the symphysis. In the Piltdown jaw, although preserved in this particular region, a fossa and a lower surface is completely absent, the sharply edged border continuing immediately to the far projecting lower frontal surface (textfig. 56). The picture is strikingly similar to that in orang where a digastric fossa is also missing (textfig. 49). It is particularly instructive to study carefully the projecting frontal part of the Piltdown jaw and to compare it with that of orang on the one hand, and with that of *Sinanthropus* on the other.

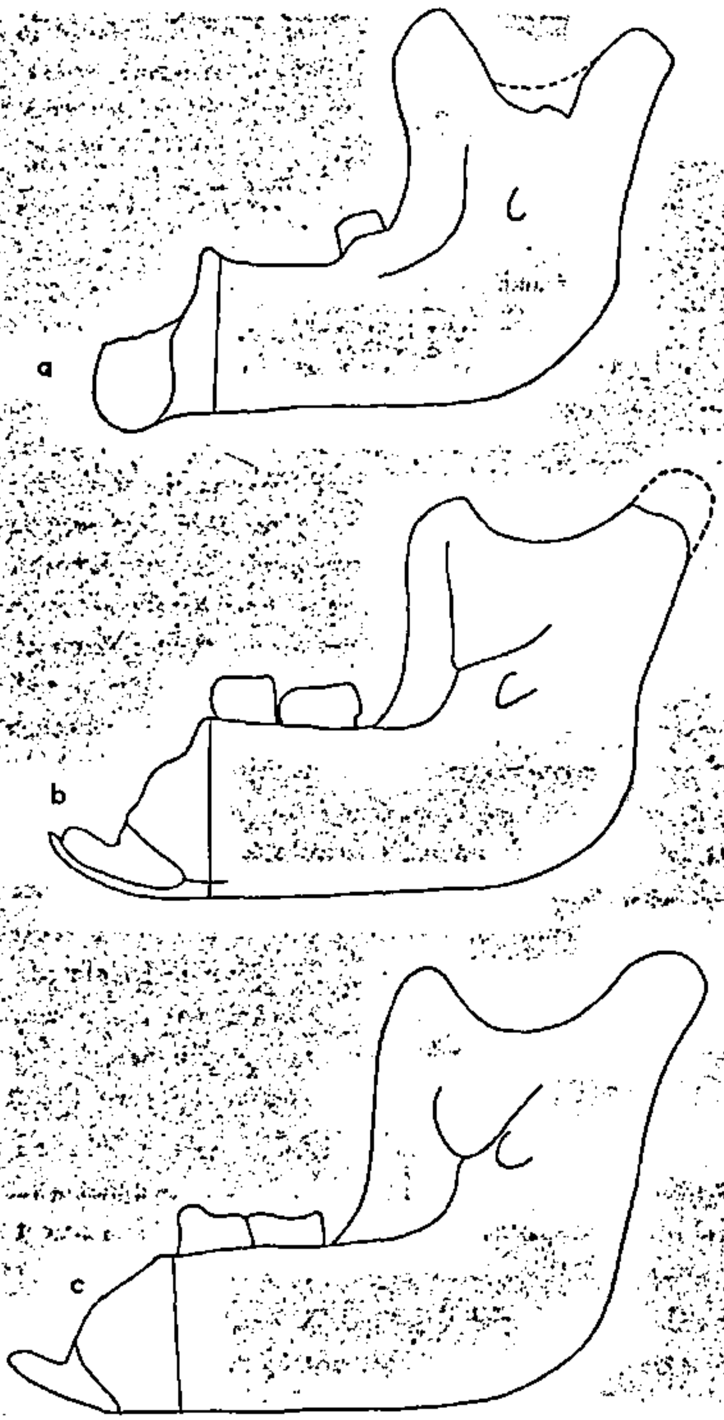

Figure 100. Diagrams in profile views comparing the Piltdown mandible (b) with that of a female orang (c) and female *Sinanthropus* H I (a). The cross sections of the frontal parts correspond to the line of breakage in the Piltdown jaw. × 2/3.

In order to obtain a better understanding for such a comparison, I cut through an orang jaw and a cast of *Sinanthropus* jaw H I at the same place where the Piltdown jaw is broken off. Textfigure 100 makes it evident that there is practically no difference between orang (textfig. 100 c) and Piltdown (textfig. 100 b), while *Sinanthropus* (textfig. 100 a) presents a completely different appearance.

Therefore, a direct parallel cannot be drawn between the Piltdown mandible and that of *Sinanthropus*, the former representing a distinct anthropoid type and the latter a distinct hominid type. Since the Piltdown mandible represents a new fossil anthropoid type, Friederichs and the writer (1932) decided to term it "Boreopithecus dawsoni." Thus, the Piltdown mandible does not approach *Sinanthropus* any closer than the orang. It is also impossible to say that the Piltdown jaw is more primitive than that of *Sinanthropus* because the former does not come within the line of evolution from which *Sinanthropus* was derived. As demonstrated in my publication on the chin (1935) and in the section concerned in this publication (p. 108) the character of the anterior alveolar arch and the relation between the milk teeth and permanent dentition indicate that the immediate forerunner of man, including *Sinanthropus*, could not have descended from a type similar to that of the present day anthropoids. I consider gorilla, orang and chimpanzee to represent highly specialized forms removed from the human line, with *Boreopithecus* (Piltdown) mandible belonging to this group.

The Heidelberg mandible. Among the hominid jaws the mandible of Heidelberg occupies a special position, due apparently to the high antiquity attributed to the fossil immediately after its discovery. Schoetensack (1908) when comparing this mandible with those of the Neanderthal group then known, especially with the jaws of Spy I and Krapina, arrived at the conclusion that the Heidelberg mandible had to be considered as "preneanderthaloid." Because at the same time it revealed even "preanthropoid" characters, and according to Huxley's determination it represented "quite a fundamentally generalized type". Since Schoetensack's statement was generally acknowledged as correct, I was inclined in my earlier publications on *Sinanthropus* to group the Heidelberg man in line with *Sinanthropus* (and *Pithecanthropus*) as equal representatives of the same hominid type. However, since I have had the opportunity of studying the original material of *Sinanthropus*, especially that of the teeth, and since additional material of mandibles has become available, I was forced to revise my earlier understanding. In addition, certain geological conditions pertaining to the Heidelberg find have become doubtful. It may be that the mandible is younger than formerly estimated and belonging to the second (Mindel-Riss) Interglacial age. On the other hand, another hominid skull has been discovered lately in the gravels of Steinheim (on the Murr, Württemberg) which is considered to belong to at least the third Riss-Würm Interglacial age, if not to an older period. Berckhemer (1933) in briefly describing the new discovery came to the conclusion that this Steinheim skull, although its general appearance is that of the Neanderthal type, approaches recent man more than the latter type. Judging from the cast of the skull at my disposal, I agree with that author. There is no doubt that the Steinheim skull when viewed from the morphological standpoint represents a much more advanced form than the classic Neanderthal man of the following geological age. In my publication on the Weimar-Ehringsdorf skull (1928) attention was called to the fact that although this skull fell within the last (third) Interglacial period it reveals the same peculiarity. Therefore there is no escape from the conclusion that in Europe, during the Middle Pleistocene, hominids lived whose morphological appearance indicate a much more advanced stage of evolution than those found in the Upper Pleistocene in the same region of the continent. Furthermore, the adult jaw of Ehringsdorf has clearly a more primitive character than the mandibles of Krapina, although both types belong to the same (third) Interglacial age.

Thus, geological antiquity of hominids finds in Central Europe does not seem to guarantee morphological primitiveness. The pretended high age of the Heidelberg fossil in itself does not decide anything in regard to the phylogenetic procedence of this particular form.

In the case of *Sinanthropus* the matter is somewhat less complicated in so far as it seems rather likely that *Sinanthropus* belongs to an earlier or at least to the same geological age as the Heidelberg jaw. In any case the morphological facts have to be considered as decisive factors for phylogenetic classification. For the time being, I shall include the preliminary results obtained from a comparative study of the teeth which will be published in detail in my next paper. These prove that the teeth of the Heidelberg jaw show none of those striking pithecoid-like peculiarities which characterize *Sinanthropus* (compare Weidenreich, 1936 a, b). Furthermore, it is well known that the teeth of the Heidelberg mandible are relatively small and do not exceed in size large teeth of recent man. In *Sinanthropus* we have two types of teeth, a large and a small one. The Heidelberg teeth correspond to the small type of *Sinanthropus,* but whereas in the latter a remarkable coincidence is existent between the size of the teeth and that of the jaw, in the Heidelberg jaw small teeth are combined with a very bulky jaw which is certainly no indication of primitiveness. In addition, the mandible itself presents a typically distinctive character. As shown above (p. 102) the alveolar and dental arches of all the available *Sinanthropus* mandibles form an equally rounded frontal curve while the anterior arcade of the Heidelberg mandible is flat so that the canines are arranged in approximately the same straight line as the incisors (compare textfig. 77).

Apart from the general robustness of the Heidelberg jaw and beside those peculiarities common to mandibles of the Neanderthal group, there are only three particularities with a special character: (1) the deep incisura submentalis combined with a strong downward projection of the torus marginalis and the forward inclination of the basal plane in comparison with the direction of the alveolar plane, (2) the extraordinary breadth of the ramus, (3) the lowness of the coronoid process combined with a shallow mandibular notch. All these three features are absent in *Sinanthropus* or at the utmost only faintly developed. As discussed in the respective chapters, there is no proof at all that these peculiarities really represent primitive characters which would stamp the Heidelberg mandible as a hominid prototype. In regard to the second and third of the enumerated points, both are found to occur to the same degree in recent Eskimo. This fact proves that we are dealing with a peculiar differentiation which was perhaps transmitted to this race. As the remaining mankind of today fails to have these peculiarities as a common character and as *Sinanthropus* undoubtedly presents herein a more general type in so far as its type is in correspondence with that of anthropoids and recent man, the distinction of the Heidelberg jaw becomes evident. The same holds good for the first of the three peculiarities. I have shown above (p. 33 & ff) that the incisura submentalis is in part a result of a strongly developed torus marginalis and that the latter formation is to be considered as the cause of the inclination of the basal line. The entire combination may be found to a certain extent to exist also in the mandibles of the Neanderthal group, so that it is only the exaggerated form which characterizes the Heidelberg jaw. Although in the male *Sinanthropus* jaw G I which is of the same or perhaps in some regard of a greater bulkiness than the Heidelberg fossil the symphysis is not preserved, yet it can be concluded from the well developed and projecting torus marginalis that an incisura submentalis also existed.

Hence, when combining in our consideration the characters of the teeth and those of the mandible, the Heidelberg jaw turns out to be a special hominid type within the order of mandibles of the Neanderthal group. That the Heidelberg fossil exhibits special features in some of its details is of no significance, since the Neanderthal group as a whole does not show a uniform appearance in the different parts of the mandible.

The mandibles of the Neanderthal group. In the preceding pages I often referred to these jaws. Viewed from the morphological standpoint, great differences exist between the individual representatives of this group, a condition which may be well observed by studying the jaw of the Ehringsdorf adult on the one hand, and that of Spy I on the other. If we keep in mind that the mandibles of recent man also differ rather widely as for instance the jaws of strongly prognathous Negroes in contrast to the orthognathous Europeans, then we come to the conclusion that we must search for such features which characterize the whole type. In regard to the mandibles this is not always an easy task, because the criterion used for attributing a given specimen to a certain group is less frequently based on its morphological appearance than on its geological condition or its pertaining to a skull with well known characters.

By comparing the mandibles of *Sinanthropus* with those of the group under discussion, it may further be noted that the former also represents two different forms which could only be attributed to the male and female type of the same hominid, because of the common character of the teeth and because of the same conditions under which the two types of mandibles were recovered. Hence, it is not surprising that the female *Sinanthropus* mandible H I bears a closer resemblance to La Naulette and Malarnaud, which are also considered to belong to female individuals by most of the authors, than the male *Sinanthropus* mandible G I. By such a comparison it will become evident that the *Sinanthropus* mandible H I shows a greater inclination of the frontal part than those two mandibles (*Sinanthropus* H I = 60.5°, La Naulette = 65.0°, Malarnaud = 70.5°), while the incurvatio anterior mandibulæ is much more pronounced in the latter. This indicates that in these jaws of the Neanderthal group the formation of a mentum osseum is in a more advanced stage. As to the alveolar arch, that of the Malarnaud mandible is much more open than that of the *Sinanthropus* jaw H I, while that of La Naulette approaches the latter. In the mandible of La Naulette the torus alveolaris superior and the fossa genioglossi are well developed, a condition not found in the *Sinanthropus* jaw H I, whereas the mandible of Malarnaud approaches the latter in this respect. In both the Neanderthal mandibles the whole relief of the outer and inner surface is not so distinctly defined as in the *Sinanthropus* jaw H I.

As mentioned in the section discussing the mandibles of Krapina D, E and G which perbably also belong to female individuals, these show many features rather similar to those present in *Sinanthropus* jaw H I, while the apparently male Krapina jaw I differs in essential points from the corresponding *Sinanthropus* mandible G I with the latter displaying more primitive characters. There can be no doubt that from all the mandibles attributed to belong to the Neanderthal group, that of the Ehringsdorf adult is closest to *Sinanthropus* and not only that, it exceeds it in some details such as the development of the planum alveolare and of the fossa genioglossi, provided that these features actually are indications of primitiveness as they seem to be at first sight. In the Ehringsdorf jaw we meet the same shape and the same curve of the alveolar and dental arch as existent in *Sinanthropus* as well as the same distinct development of the outer and inner relief of the body. However, it is not permissible to place the Ehringsdorf mandible directly in line with the *Sinanthropus* jaw because of the evident differences in characters of the teeth. I will return to this problem in my next publication.

The male *Sinanthropus* mandible G I may at most be compared with the jaws of La Chapelle-aux-Saints and Krapina I, the latter being of about the same size and robustness. However, both differ from *Sinanthropus* in their angle of inclination (*Sinanthropus* G I = 59.5°, La Chapelle-aux-Saints restored 70.5°, Krapina I 63.5°) and in the mandibular angle (*Sinanthropus* G I 97°. La Chapelle-aux-Saints 110°, Krapina I 117°). Furthermore, they differ in the development of the muscle markings of the ramus. *Sinanthropus* shows a deep fossa masseterica combined with a strong eversion of the angle and a not less strong development on the medial surface of the ramus — tuberculum pterygoideum superius and inferius. All these peculiarities are lacking in the two Neanderthal mandibles, although they are not inferior to the *Sinanthropus* jaw in robustness and size. On the other hand all three mandibles in question possess a tuberculum condyloideum externum of the same strength and distinctness.

The mandible of Kedung Brubus. In 1890 Dubois found a fragment of a mandible in the so-called Kendeng deposits, descriptions and illustrations of which were given much later (1924). Dubois attributed this specimen as belonging to *Pithecanthropus* and it may therefore be justified to include it here. Since nothing but a small triangular piece is preserved representing the lateral surface of the jaw body in the region of the first left premolar and canine and the adjoining part of the lower border, it is somewhat difficult to determine the real character of the specimen. My examinations are based on a well made cast. For illustrations the reader is referred to Dubois (1924, Plate VIII, figs. 12-15) and Hrdlicka's work (1930 a, Plate VIII, fig. I).

No doubt, the body of the mandible is low, its height being about 27.5 mm, this measurement being taken between P_1 and C (*Sinanthropus* H I=28.2); the thickness in the same region is about 16.5 mm, so that the index, although not in exact accordance with the regular index of robustness, is 60.0 In *Sinanthropus* H I the thickness measured in the same place is 14.6 mm, its index 51.8. Compared with *Sinanthropus* the mandible in question is at least of the same robutness even if we suspect that a small part of its alveolar border is broken off. We are therefore dealing with a low and thick mandible ranging within the order of those of *Sinanthropus* and Malarnaud and apparently belonging to a female individual according to the discussion in a preceding paragraph. In the same level the lateral surface shows just at the lower margin a distinct swelling which is to be considered as the tuberculum marginale anterius. It has nothing in common with a lateral tubercle of the mental trigonum. However, the most surprising aspect is presented by the lower margin. The latter is formed by a uniform broad and approximately smooth plane the lateral border of which coincides with the lower border of the mandible itself. The medial border of this plane is just recognizable. This plane cannot be anything else but a part of the digastric fossa. However, that which is strange is the breadth of the fossa which is without parallel among all known hominid mandibles. Another peculiarity of the fossa is that it is situated completely at the lower margin of the mandible, being only somewhat inclined toward the lingual border of the margin. This position corresponds exactly to that recognized as characteristic of *Sinanthropus*, and to a certain degree also of some of the Krapina jaws. The only difference is the great breadth of the fossa in the Java mandible. Therefore, I believe, that the mandible may belong to *Pithecanthropus* or to the nearly discovered Neanderthal type of Java, *Javanthropus soloensis*. Unfortunately, the only tooth present (P_1) is so badly preserved, with the crown missing completely, that it cannot be used for a better diagnosis. The fact that the mesio-distal diameter of the root is very small in comparison with the labial-lingual one is strange and different from *Sinanthropus*.

VII. THE POSITION OF THE *SINANTHROPUS* MANDIBLE IN THE LINE OF EVOLUTION

A great deal of misunderstanding in judging primitiveness of a given mandible has been caused by the tendency already mentioned above to consider all peculiarities apparent in a mandible of high geological antiquity as peculiarly characteristic for the entire stage of evolution concerned. It is commonly overlooked that in most cases only a single specimen is available which could never indicate the degree of variability existing throughout that particular period. Furthermore, it is overlooked that a great variation also occurs in recent man and that most of the variations are not confined to a special race but are identical for mankind as a whole. *Sinanthropus* moreover shows that in the mandibles of early hominids the difference of sex is strongly pronounced, much more than in recent man, and that this difference is reflected by special morphological features.

The task of finding a genuine primitiveness which could be considered as the starting point of evolution of at least a certain hominid stage is made slightly easier in the case of *Sinanthropus* on account of the great number of individuals, male and female, adult and juvenile. This being the case, it is possible to fix with a certain degree of certainty the common character typical for *Sinanthropus*. However, the question is whether or not the so established characteristics hold good for all forerunners of present mankind. Just to mention an example, I believe that *Sinanthropus* is in closer relation to the Mongolian race of today than to Negroes or to any other race. The reason for being of this opinion is explained above (p. 60). In this connection it is surprising that a planum alveolare so strongly developed in the Ehringsdorf adult jaw and, also very distinctly though less pronounced in the Heidelberg mandible, is almost completely absent in all *Sinanthropus* mandibles. Does this mean that we have two lines of evolution, one with a planum alveolare extending through fossil types like those just mentioned, and another one without such a formation, extending through *Sinanthropus*? This question cannot be answered by referring to anthropoids, for as described above this planum is well developed in gorilla, less in chimpanzee and entirely absent in orang. Does this line of evolution leading to Ehringsdorf and Heidelberg man start from a gorilla-like anthropoid and that of *Sinanthropus* from an orang-like type, or does the mandible of Ehringsdorf represent a much earlier stage which *Sinanthropus* has long surpassed? The first of these possibilities is to be excluded because it contrasts to all other known facts. The second possibility presents a somewhat different aspect.

As pointed out in my lecture delivered at Tokyo (1936 b) one of the most amazing characteristics of *Sinanthropus* is the fact that teeth resembling entirely those of recent man are found side-by-side in the same jaw as teeth of the most pithecoid type of hominid teeth ever discovered. *Sinanthropus* jaw B I shows this phenomenon incontestably (Plate II, fig. 5). This jaw is remarkable for its relatively wide alveolar arch which rather contrasts those of the adult jaws. The roots of the four permanent incisors fully erupted differ from the corresponding teeth of recent man only by their length and thickness but their crowns reveal no other differences. Even the lingual tubercle so pronounced in lower incisors of some of the mandibles of the Neanderthal group is not strongly developed. On the other hand, the first and second premolars the germs of which are embedded in the mandible and exposed by an accidental fracture (Black 1929) undoubtedly have a closer resemblance to the corresponding teeth of chimpanzee than to those of recent man. This is especially true for the second premolar of which even the outline no longer bears any similarity to that of recent man. In Plate II, fig. 5 this tooth is reproduced *in situ* from the original but unfortunately the reproduction is so poor that the interesting details are difficult to recognize. In my publication mentioned above (1936 b) photographs of the two premolars in question are reproduced, but all other illustrations connected with the teeth will appear in a following publication.

These peculiar conditions of the teeth are analogous to those of the mandibles of *Sinanthropus.* In the latter we find a well developed mental spine nearly identical with that of recent man combined on one hand with the complete absence of a torus alveolaris superior (planum alveolare) and a fossa genioglossi and on the other hand with such long and thick roots of canines and incisors and so large a corresponding root area at the frontal part (textfigs. 15-30) as has never been observed in any fossil hominid.

Considering all these facts there is only one possibility of interpretation. First of all, there is not the least doubt that *Sinanthropus* is to be considered as a direct forerunner of recent man. This is proven by the fact that the torus mandibularis, a formation distinctly characteristic for recent man, especially for Mongolians, but without any fundamental significance was already fully developed in *Sinanthropus* presenting the same appearance and located at exactly the same place as in recent man. It is furthermore proven by the entire conformity of more general features such as those of the permanent lower incisors and the inner surface of the frontal part of the mandible. The features characterizing recent man have undergone a lengthy process of evolution. Separate stages of this general process are represented by certain fossil types like *Sinanthropus*, Neanderthal man, etc. In the case of the mandible the general trend of evolution is obviously the reduction of the masticatory apparatus, not so much the reduction of the posterior part involving the molars as that of the frontal part involving the incisors, canines and premolars. Here the reduction is manifest by a decrease of bulkiness of the teeth, effecting the crowns and in particular the roots. The reduction is accompanied by a diminution and receding of the frontal part of the alveolar process causing the protrusion of the mentum osseum and in consequence resulting in a new arrangement of the frontal teeth in a straighter frontal line. The decrease of general robustness of body and ramus is also revealed by the constructive framework of the mandible: the male *Sinanthropus* jaw G I is in all parts of an evenly bulky appearance and the details of the relief therefore are much less marked than in the weaker female *Sinanthropus* jaw H I where the constructive parts of the mandible in the form of tori and cristæ represent the characteristics of the surfaces. The change in the course of evolution of these differences is very slight, we are therefore dealing essentially with a general relative diminution. In the same sense is to be understood for instance that in recent man the ramus is less steep than in the bulky *Sinanthropus* jaws.

The most surprising fact revealed by the mandible of *Sinanthropus* and its comparison with those of other hominids is that only the general line which human evolution follows may be traced to the remote destination for which it is bound. Single "stops" on the road as manifested by special features of teeth or bones are not at all realized by one and the same specimen or in the same phylogenetic age. In other words, regressive and progressive characters may be closely associated and are found to a certain extent in every fossil mandible. The Heidelberg jaw combining a primitive mandible with a peculiarly developed ramus and rather advanced features of teeth represents a particularly good example in this respect. A real zigzag course is never taken by evolution.

The whole literature concerning fossil man contains a great deal on specialization and generalization. No sooner is a horminid type discovered then someone declares that we are dealing in that case with a specialized type branching off from some stage of the general line of human evolution. Most often convincing reasons for such an interpretation are not given or if so they are not sufficiently firm to stand a careful examination. In the description of the ramus (p. 72 & ff) examples were given in this respect.

Frankly speaking, no authority whosoever is able to say with a certain degree of certainty whether or not a special feature occurring in one of the fossil hominid specimens represents a real specialization of that particular kind whereby the whole type is marked as the representative of a discontinued branch-line. In one of my last lectures (1936 a) I said: "It cannot be decided what a real specialization has been, before the whole phylogenetic development of the species and all its variations have come to light." Just to give an example as to how much opinions may differ, I recall that W. Abel (1931) deduced from the pattern of the *Australopithecus* molar the high specialization of this anthropoid, while Broom (1933) considers this fossil on the basis of the same feature as a generalized type and in any case a forunner of man. I believe that it is quite impossible to deduce from one single specimen of a given type, that is to say, without knowing the extent of its variation, whether or not it could have given origin to a type somewhat different in certain details. And even if we know that a great variation exists as in the case of the Neanderthal group, then the difficulty is not less because only one of these variations may have been the starting point of the main line. In the case of the Heidelberg mandible it was proven above that the same enormous breadth of the ramus combined with a very low coronoid process and flat mandibular notch occurs in the present day Eskimo. This feature looks more like a specialization than a generalization for which Schoetensack had taken it in the Heidelberg jaw. At a time at which the terms "phenotype" and "genotype" are so generally used and misused, it may be superfluous to emphasize that an individual with a mandibular ramus like the Heidelberg man may nevertheless have a direct descendant with a narrow and high ramus: *Mutatis mutandis;* the same may hold good for all the other peculiarities relevant to a fossil hominid type. I know, I shall be referred to Dollo's law, according to which there is no return from a special direction once taken in evolution. I do not have the least intention of disavowing the validity of this law when considering the whole evolution of a species. However, the difficulty is that we do not know whether in a special detail the margin beyond which there actually is no return has already been transgressed. The reader is referred to my earlier publication on the reversibility of evolution (1931).

In this connection it may be of interest to determine whether the mandibles of *Sinanthropus* present a particularity which could be considered a "specialization." The torus mandibularis which seems most likely to be one certainly is not, because it occurs unchanged in recent man. However, of what significance is the multiplicity of the foramen mentale? This feature is characteristic for *Sinanthropus* but is rare or never found in the same degree in recent man. Nevertheless, it cannot represent an irreversible "specialization" as neither the number of the foramina nor their position is fixed. The three adult mandibles show 3 different numbers: five, four, three. Besides, the special arrangement of the foramina is likewise quite different in each specimen. Moreover, at least three foramina occur also in recent man. As these two peculiarities are the only ones which may be suspected of being a "specialization", the mandible of *Sinanthropus* really represents a "generalized" type also in the commonly acknowledged sense.

As to the general character of the mandibles of *Sinanthropus* Davidson Black (1929) came to the following conclusion: "In adult *Sinanthropus* the architecture of the jaw appears to be much less hominid than that of the teeth which it supports and, as in the immature specimen, represents a framework which till the discovery of *Eoanthropus* has been supposed to be associated only with anthropoid types of dentition. It can no longer be doubted, that distinctive hominid teeth characters were evolved in the human family long before the architecture of the supporting jaw lost its anthropoid form." When Davidson Black wrote these sentences only one adult mandible (Jaw A II) and one juvenile jaw (B I) were known to him. I doubt whether he would have expressed his opinion in this way if he would have had the opportunity to examine all specimens of *Sinanthropus* mandibles and all teeth which are now at hand. For the gist of his words is that the mandible of *Sinanthropus* has an anthropoid appearance while its teeth are human-like. As a matter of fact neither the first nor the second statement is entirely true and cannot be claimed to indicate the leading character. As I have proven by the preceding discussion, *Sinanthropus* presents a real mixture of pithecoid and human peculiarities. That which decides its significance and position in the line of evolution is the fact that the pithecoid characters partly prevail and that they are much more distinct than in any other fossil hominid type known hitherto. Considered as a whole *Sinanthropus* undoubtedly comes closer to the supposed anthropoid forerunner than the Heidelberg or Neanderthal man. One single detail does not mean much, especially if, as I have demonstrated, it can be combined with other details of a somewhat different phylogenetic character. This of course also holds good to a certain extent in regard to the mandibles. Teeth and brain case have to complete the picture, all of which fully harmonize in the case of *Sinanthropus*.

In numerous publications concerning the racial differences between the single groups of mankind of today special stress is laid upon the question as to which detail is to be considered primitive. The answer to this as far as the mandible is concerned is to be found in the preceding description of the *Sinanthropus* jaws. However, I must make one reservation. It may be that a group of mandibles found in another region although contemporaneous with *Sinanthropus* would reveal some different details. On the basis of the present knowledge of fossil man the primitive character may be only recognizable for certain features, these apparently being: a strong inclination of the frontal part, narrow mandibular and dental arcades with well rounded curves, parallelism between the alveolar and basal plane, steep and relatively broad rami, a narrow digastric fossa situated more at the lower margin, a prominent trigonum basale, strong muscular markings and distinct reliefs of the surfaces of the body and the ramus. Whether the prognathism of certain recent races is primary or more or less of secondary nature is difficult to decide for the present. Judging by McCown's most recent report on Mount Carmel Man (1936) the first eventuality is probable. It seems as if the differentiation of main races started very early so that one or the other peculiarity may have been fixed or determined in a very early stage. In this connection I refer again to the torus mandibularis.

The fact that the mandible of *Sinanthropus* approaches the anthropoid type of the primates does not require any further confirmation. The question is only which of the living species or their forerunners does it resemble most. In my publication on the origin of the chin (1934) it was shown that the appearance of the anterior alveolar arch and the proportions of the milk molars in comparison with the premolars indicate that the human ancestor must have been a special kind of anthropoid with strong and well developed canines but nevertheless with smaller and less projecting canines than the present day anthropoids have as a whole. The peculiarities of the *Sinanthropus* mandibles tell the same. Some peculiarities, as for instance, the parallelism between the alveolar and basal plane and the steepness of the rami are more similar to those obtaining in the gorilla and orang than in chimpanzee. The flatness of the lingual surface of the frontal part bears a closer resemblance to that of orang than gorilla or chimpanzee. The existence and position of the digastric fossa is the same as in gorilla and chimpanzee. The pronounced development of the muscle markings for the attachment of the pterygoidei is found to the same extent in gorilla. As to the teeth, the lower premolar reveals the closest resemblance to chimpanzee, while the pattern of the molars are not like any of the three apes.

I was able to demonstrate that a mentum osseum is absent in *Sinanthropus* but that a mental trigonum has just begun to develop. The occurrence of a small but distinct mental spine corresponds to that phenomenon. This coincidence recalls Walkhoff's (1902) theory, namely that the two formations are caused by the effect of the muscles attached to the spine, an effect which would be produced by the faculty of speech. Walkhoff supported his hypothesis mainly by means of skiagrams of the chin region which revealed a triangular space in this region in recent man, while in skiagrams of anthropoids this darkening would be completely absent. In my frequently quoted publication (1934) in which this problem was discussed in detail I showed that the bony structure which is the basis of the triangular shadow observed has nothing in common with any special muscle action. However, for the sake of completeness, I wish to point out that the *Sinanthropus* mandible H I exhibits a small but distinct shadow (textfig. 28 s) which may be expected to be in accordance with the external appearance of the region in question. Whether or not *Sinanthropus* has had the faculty of speech is a matter which cannot be decided on the basis of some morphological details of the bony structure. Yet, I see no reason why *Sinanthropus* should have been mute. The faculty of speech is certainly correlated with the transformation of the mandible in the course of evolution. This transformation again is closely connected with the long lasting transformation of the brain case and with the increase in size of the brain. Therefore, I do not believe that I am taking too great a risk in supposing that *Sinanthropus* already knew to make himself understood by words. The many indications supplied by his cultural life support this idea.

VIII. LIST OF MEASUREMENTS OF ALL THE *SINANTHROPUS* SPECIMENS

Measurements (linear measurements in millimeters)	Page reference	adult			juvenile			
		G I	H I	A II	B I	B IV	B V	F I
A. Body		♂	♀	♀	♀	♀	♂	♂
Height of the symphysis	113	40.0*	31.5					
Height of the foramen supraspinosum	85		21.5		17.0			
Height of the body	86	34.0	26.0	25.6				
Height of the foramen mentale	95		22.0		25.5			
Bimental breadth	113	46.1*	53.6*					
Thickness of the body	86	16.4	15.4	15.2				
Index of robustness	86	48.3	58.4	59.4				
Index of the position of the foramen supraspinosum	85		30.2		31.3			
Index of the position of the foramen mentale	86	33.3	35.0	33.3				
Angle of inclination (a)	80	59.0°*	60.5°		63.5°	63.0°	59.5°	
" " " (b)	83	123.0°*	114.0°		123.0°			
Angle of the molar rows	106	24.0°*	13.0°	23°*				
B. Rami								
Height of the ramus	92	66.7	59.0					
Breadth of the ramus	92	40.7	39.7					
Breadth of the incisura semilunaris	94	33.0*	34.0*					27.0
Depth of the incisura semilunaris	94	12.0*	17.2*					8.3
Index of the ramus	91	60.8*	67.3		69 8*			
Depth-length index of the incisura semilunaris	94	36.4	50.6					30.8
Index of the position of the deepest point of the incisura semilunaris	94	49.9*	36.9*					51.2
C. The mandible as a whole								
Length	97	103.0*	94.0*		80.0*			
Bicondylar breadth	97	146.4*	101.8*		108.6*			
Bigonial breadth	95	108.6*	97.8*					
Length of the alveolar arch	100	65.0*	54.0*	54.0*				
Breadth of the alveolar arch	"	63.0*	54.0*	57.0*				
Length of the anterior alveolar arch	"	28.0*	23.5*	22.0*	26.0*	32.5	28.0	
Breadth of the anterior alveolar arch	"	47.0*	47.0*	43.0*	49.0*	46.0	48.0	
Length of the basal arch	"	46.5*	42.0*		14.0*			
Breadth of the basal arch	"	68.2*	67.0*		44.0*			
Length-breadth mandibular index	98	70.3*	92.4*		73.8*			
Breadth index	95	74.1*	95.5*		81.6*			
Height index of body and ramus	97	44.0*	36.2*					
Index of the alveolar arch	100	103.3*	100.0*	94.8*				
Index of the anterior alveolar arch	"	58.3*	50.0*	51.2*	53.2*	70.5	58.3	
Index of the basal arch	"	68.2*	62.7*		31.8*			
Mandibular angle	88, 90	97°	108°		107°			112*
Angle between alveolar and basal line	96	-1.0°*	0.5°*		4.0°*			

* Measurements marked with an asterisk are taken on restored specimens.

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EXPLANATION OF

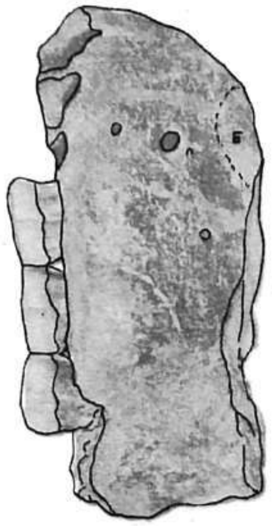
PLATE I.

PLATE I

Six telephotos of a fragment from the right side of the adult female *Sinanthropus* mandible from Locus A (A II). Natural size.

Figure 1 — labial view.
" 2 — lingual view.
" 3 — occlusal view.
4 — basal view.
5 — mesial view.
6 — distal view.

m, tuberculum marginale anterius.



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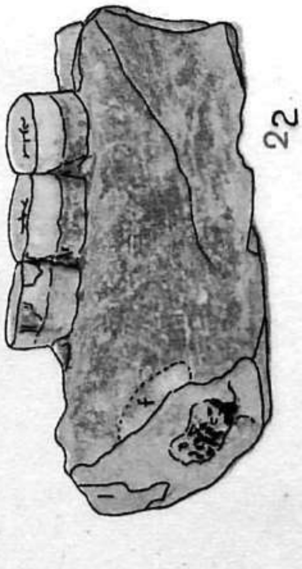

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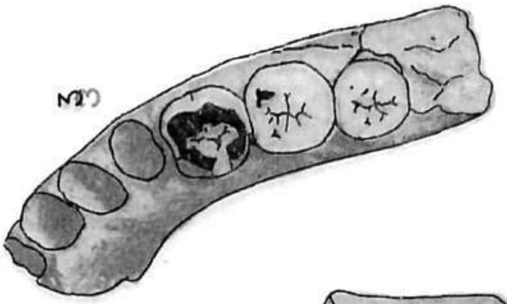

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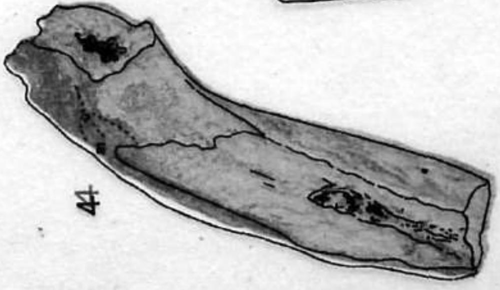

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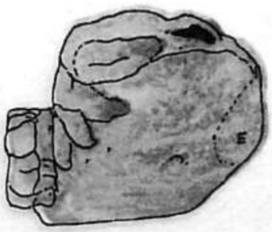

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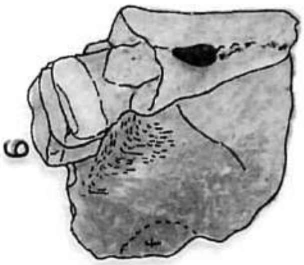

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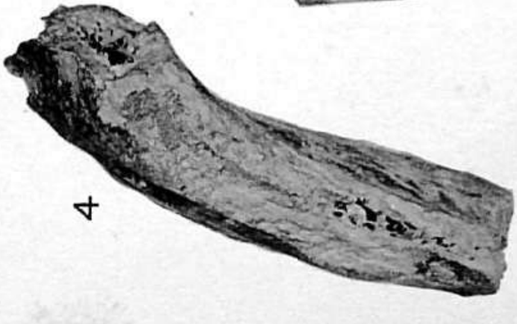

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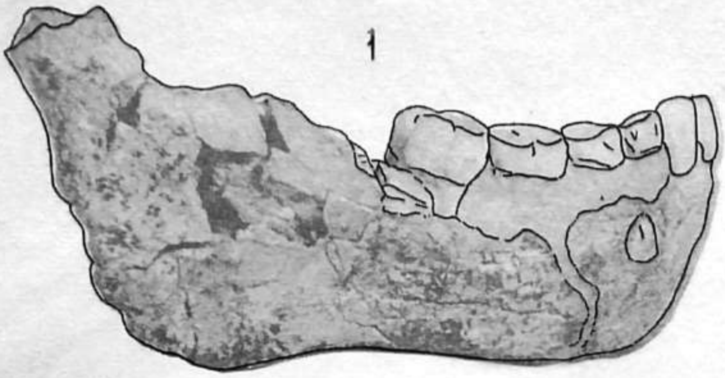
EXPLANATION OF

PLATE II.

PLATE II

Telephotos of the fragments of the right side of the *Sinanthropus* female child mandible from Locus B (B I) partly restored.

Figure 1 — labial view.
2 — lingual view.
3 — occlusal view.
4 — basal view.
5 — occlusal view of specimen in stage of restoration showing the unerupted permanent premolars *in situ*.
6 — labial view of symphysis fragment.
7 — lingual view of symphysis fragment.



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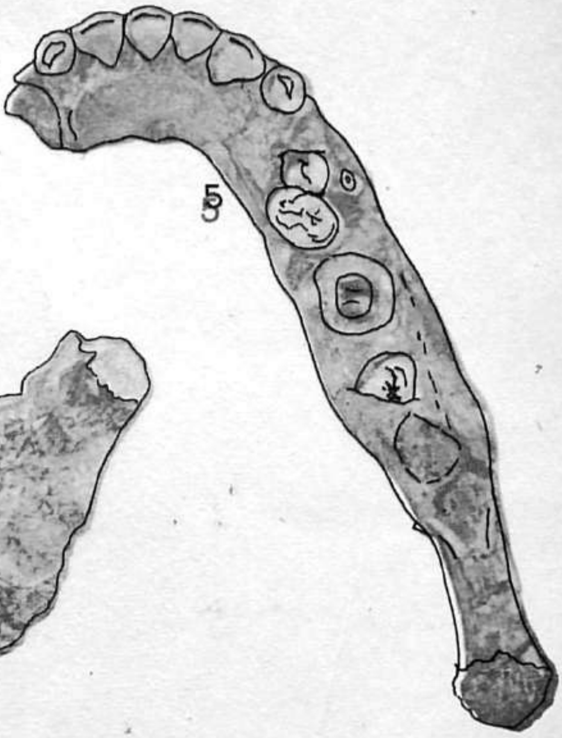

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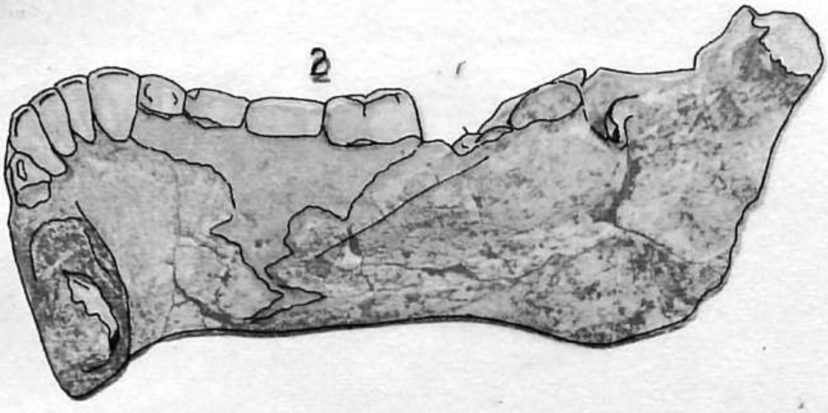

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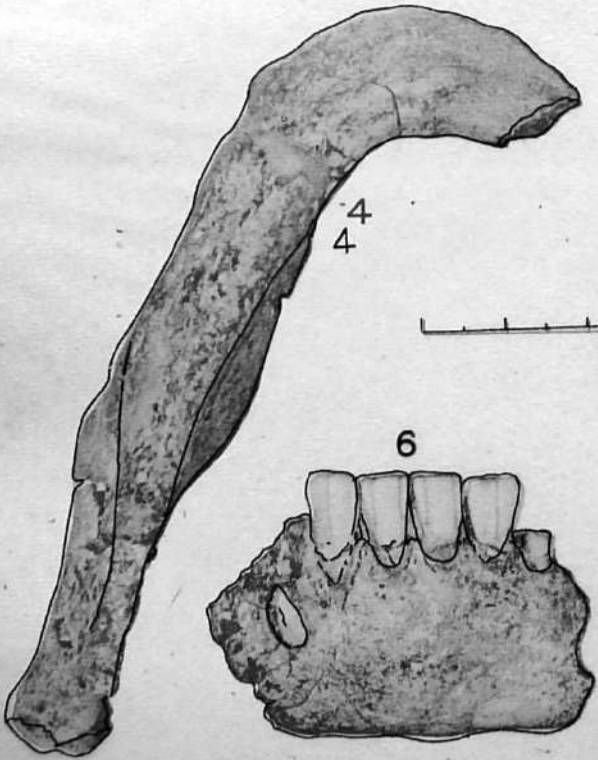

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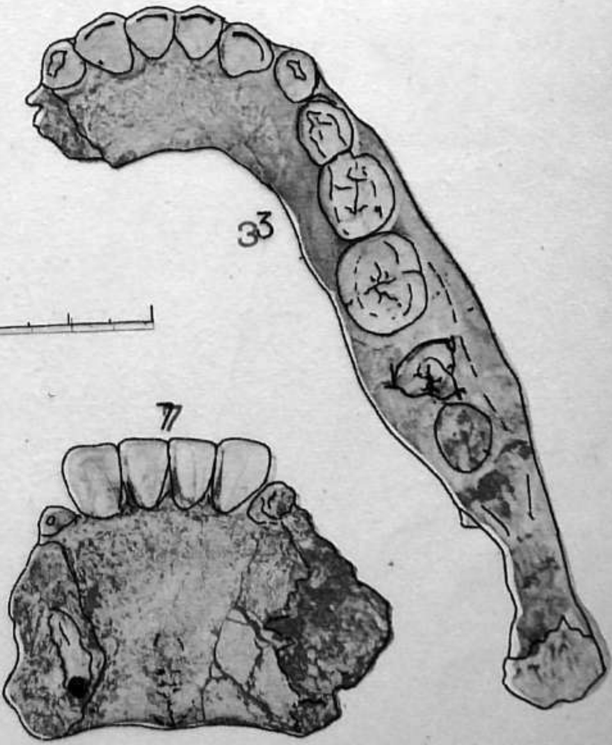

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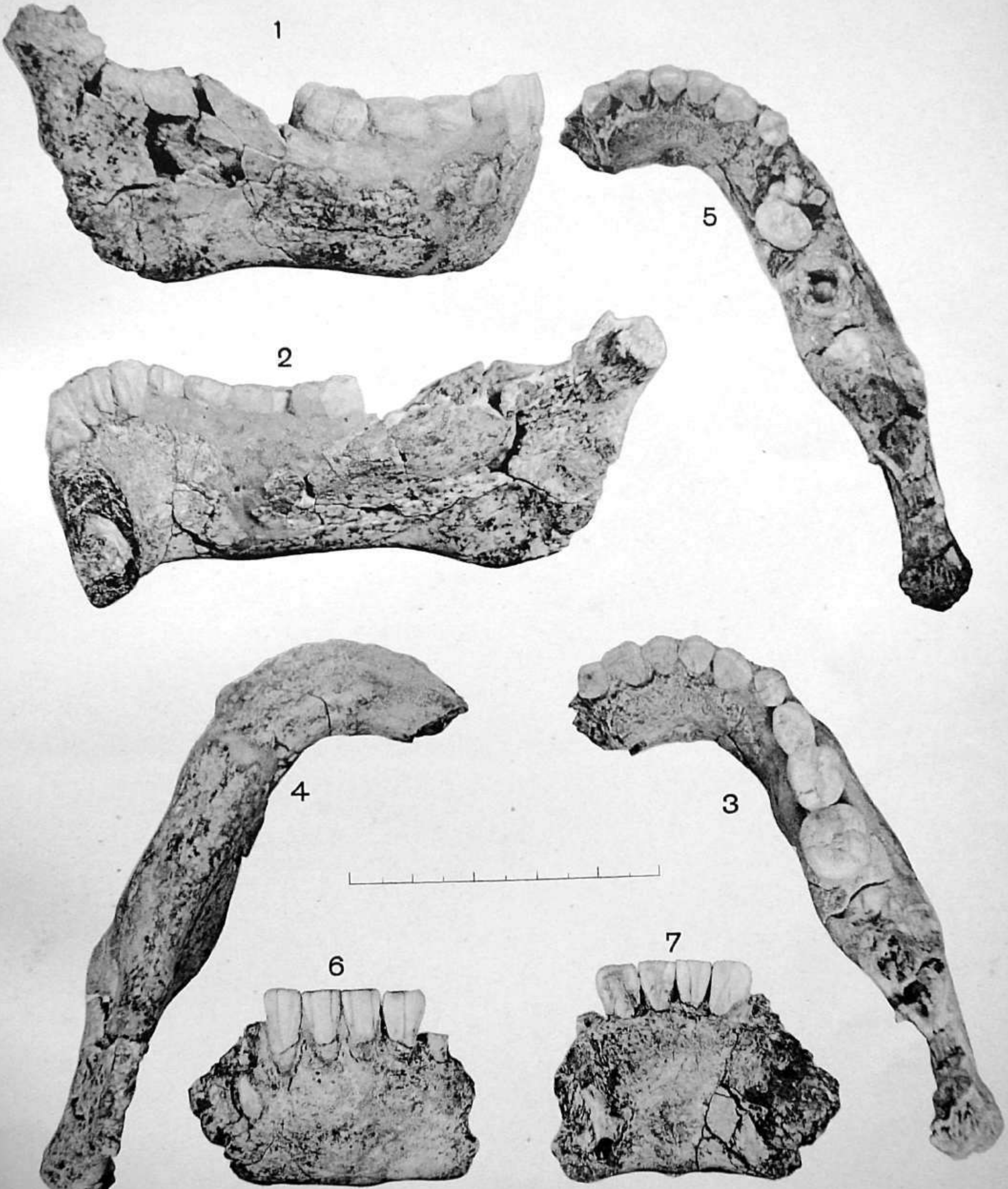
PALÆONTOLOGIA SINICA SER. D. VOL. VII, FASC. 3

Davidson Black: *Sinanthropus* mandibulae. PL. II



EXPLANATION OF

PLATE III.

PLATE III

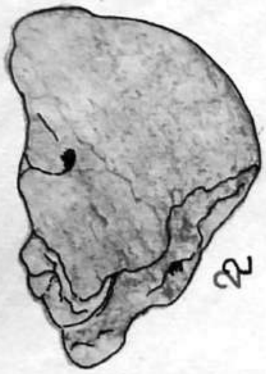
Figures 1 to 4 telephotos of the fragment from the right side of the *Sinanthropus* child mandible from Locus C (C I). Natural size.

Figure 1 — labial view.
2 — lingual view.
3 — occlusal view.
4 — distal view.

Figures 5 to 8 telephotos of the fragment from the right side of the *Sinanthropus* male child mandible from Locus F (F I). Natural size.

Figure 5 — labial view.
6 — lingual view.
7 — occlusal view.
8 — distal view.

Davidson Black: *Sinanthropus* mandibulae. PL. III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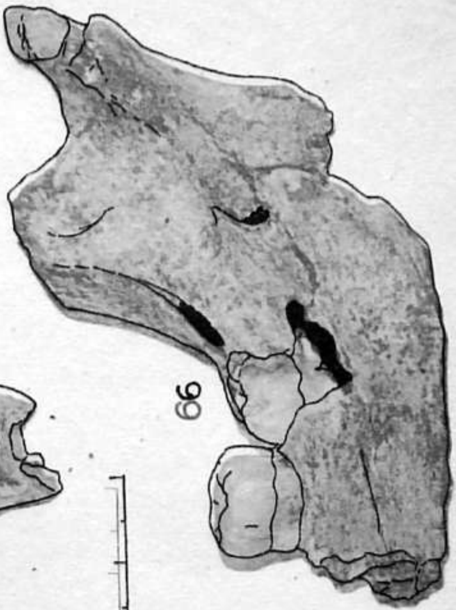
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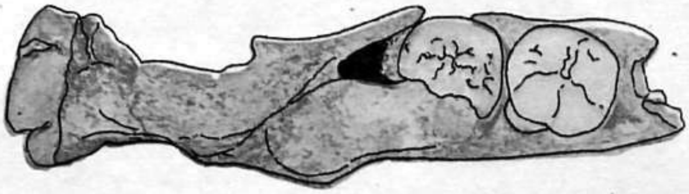
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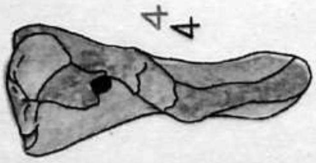
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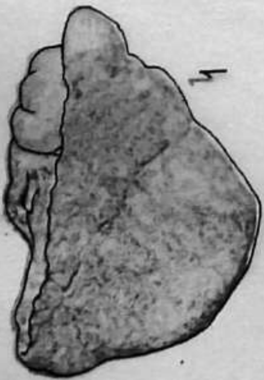
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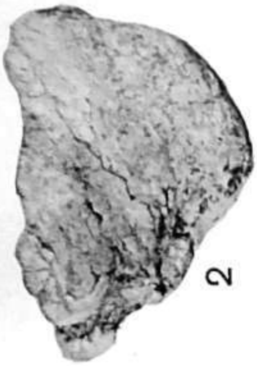
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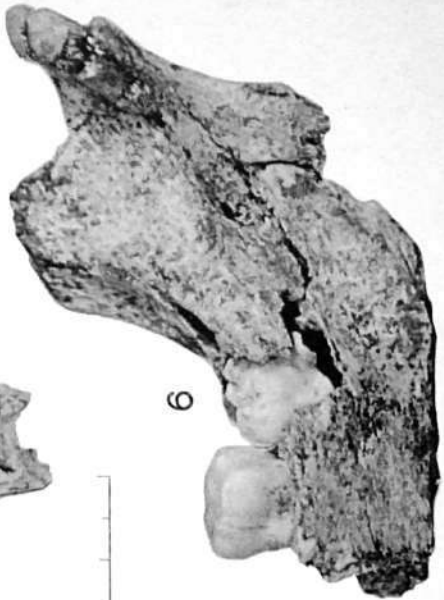
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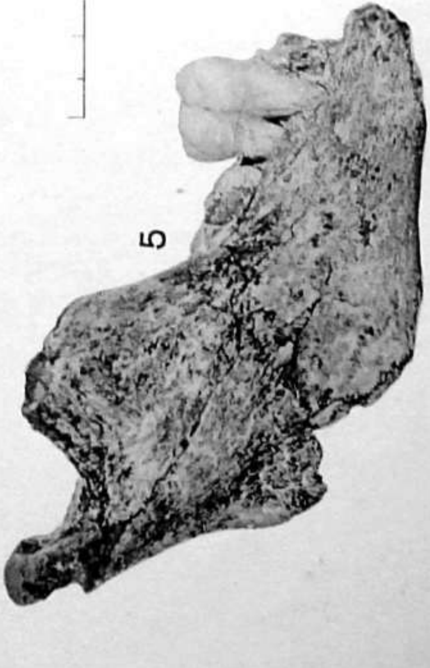
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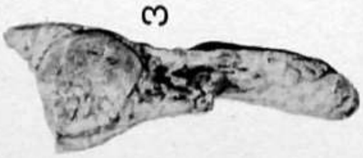
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EXPLANATION OF PLATE IV.

PLATE IV

Four telephotos of a fragment of the left side of the adult male *Sinanthropus* mandible from Locus G (G I). Formerly described as Locus G I jaw. Natural size.

Figure 1 — lingual view.
2 — labial view.
3 — occlusal view.
4 — basal view.

m, tuberculum marginale anterius.

Davidson Black: *Sinanthropus* mandibulae.

PL. IV

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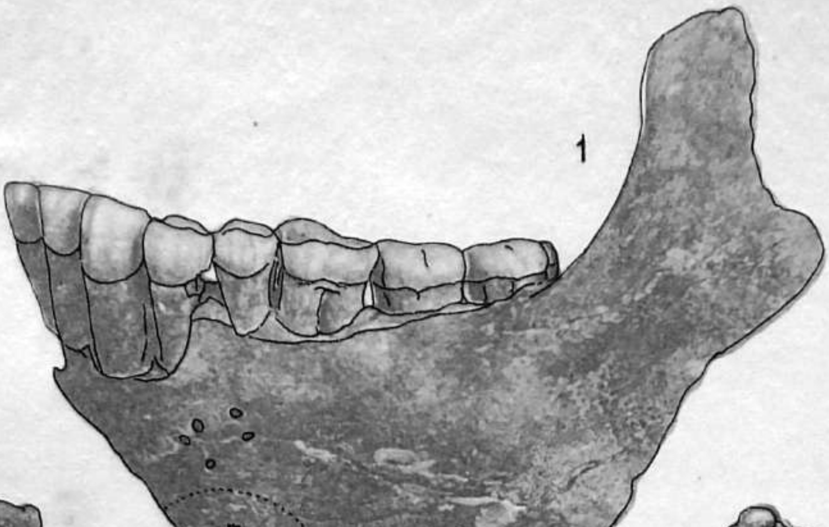

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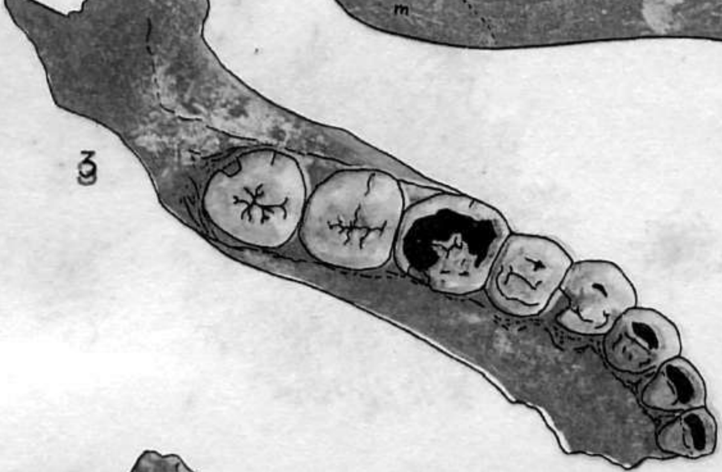

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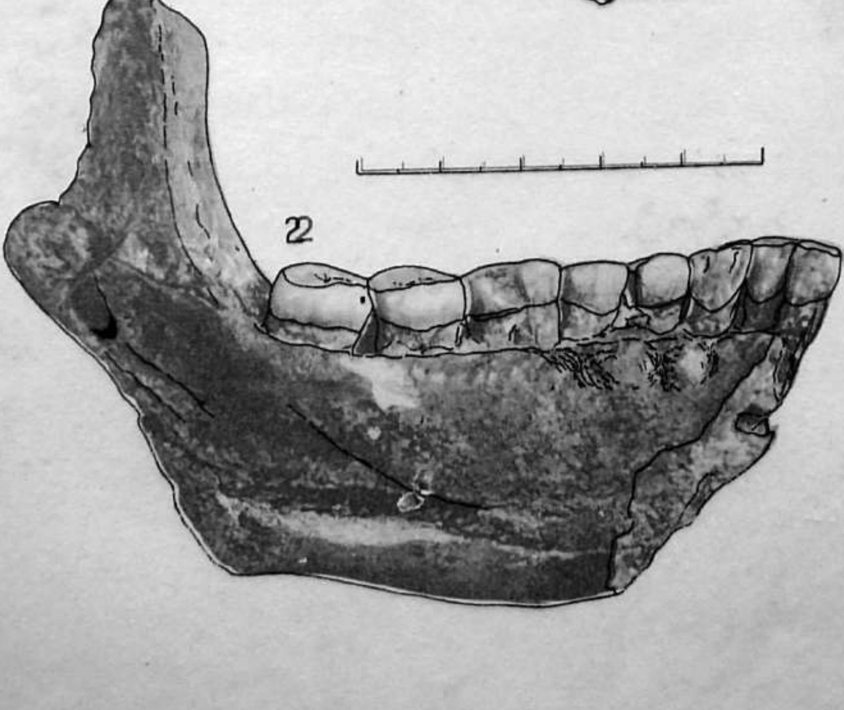

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Davidson Black: *Sinanthropus* mandibulae. PL. IV


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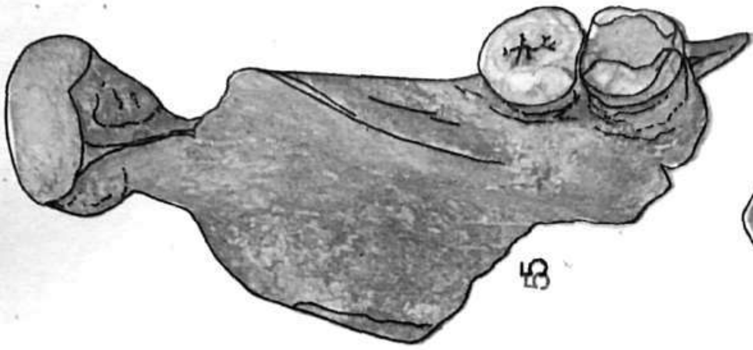
EXPLANATION OF

PLATE V.

PLATE V

Five telephotos of a fragment of the right side of the adult male *Sinanthropus* mandible from Locus G (G I). Formerly described as Locus G 2 jaw. Natural size.

Figure 1 — labial view.
2 — lingual view.
3 — occlusal view.
4 — distal view.
5 — view from the labial side and above.



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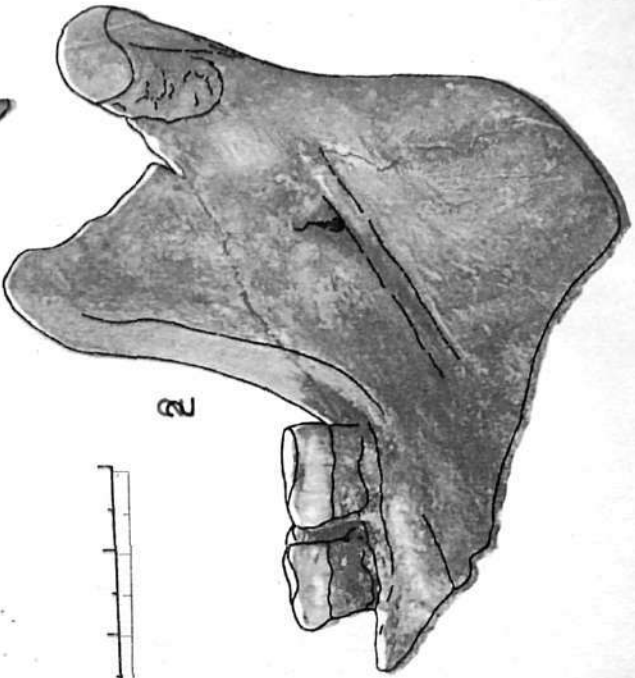

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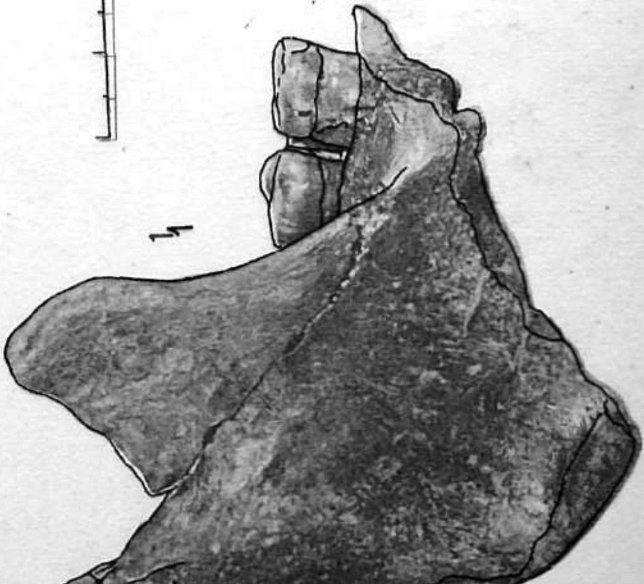

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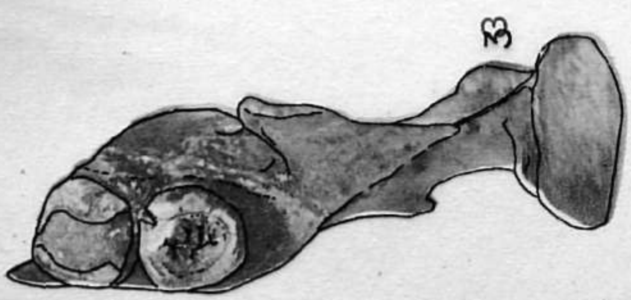

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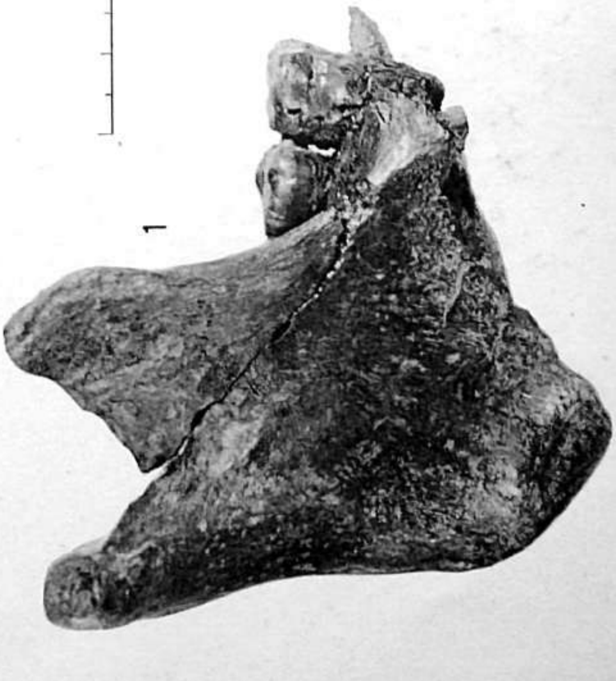
PL. V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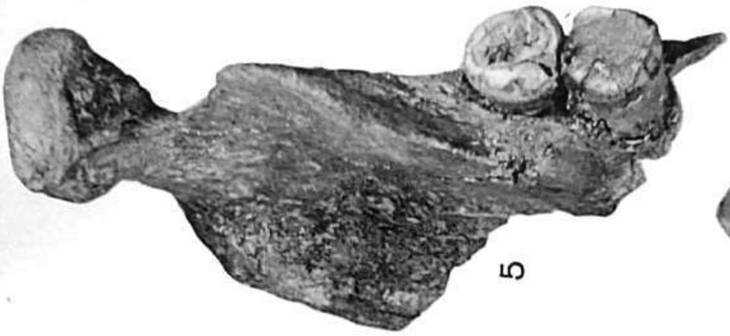
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EXPLANATION OF

PLATE VI.

PLATE VI

SKIAGRAMS

Lateral views

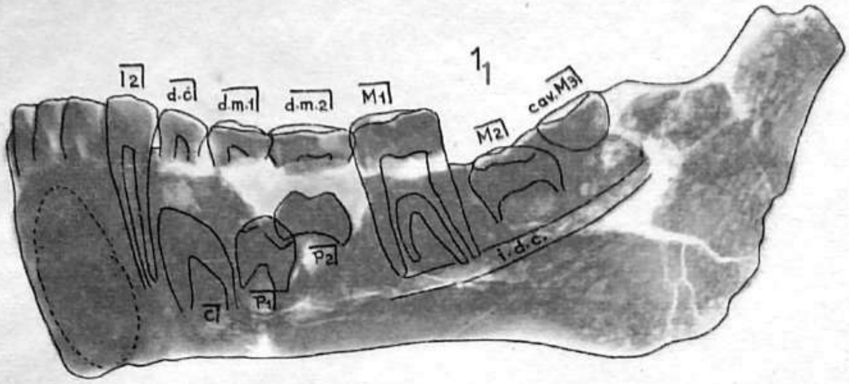
Figure 1 — *Sinanthropus* mandible B I (comp. Plate II, figs. 1 & 2).
2 — *Sinanthropus* mandible C I (comp. Plate III, figs. 1 & 2).
3 — *Sinanthropus* mandible F I (comp. Plate III, figs. 5 & 6).
4 — Modern North China child of the same age as *Sinanthropus* F I illustrated in fig. 3 of this plate.

Symphysis views

Figure 5 — *Sinanthropus* mandible B I (comp. Plate II, figs. 6 & 7).
6 — *Prehistoric* (Æneolithic) North China child of the same age as *Sinanthropus* B I given in fig. 5 of this plate.
7 — Modern North China child (No. 44) of the same age as *Sinanthropus* B I in fig. 5 of this plate.
8 — Modern North China adult male.
9 — Orang, adult female.

Davidson Black: *Sinanthropus* mandibulae.

PL. VI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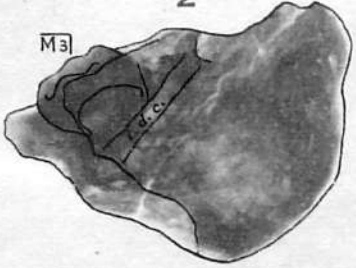

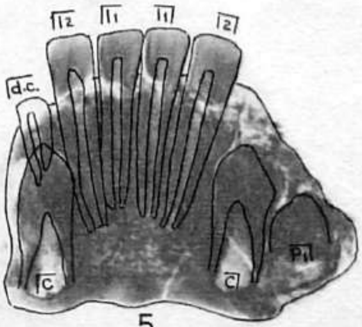
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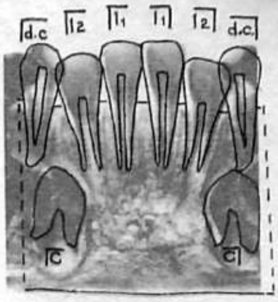
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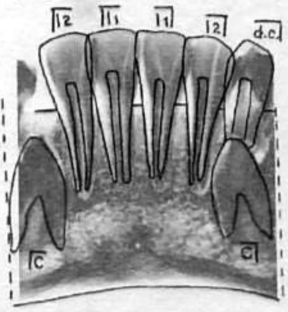
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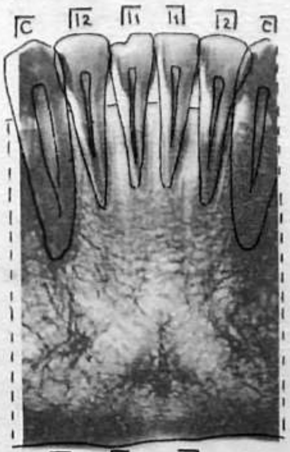
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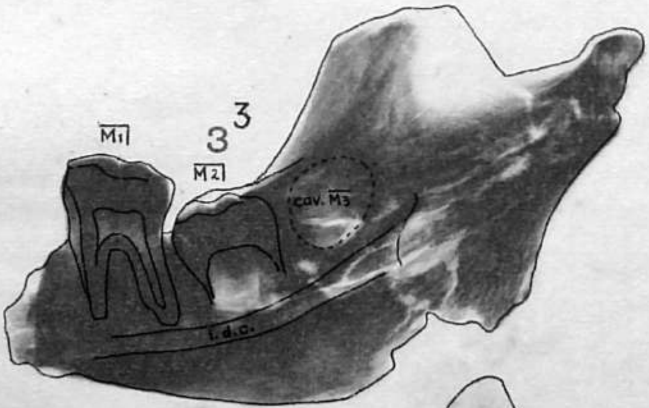
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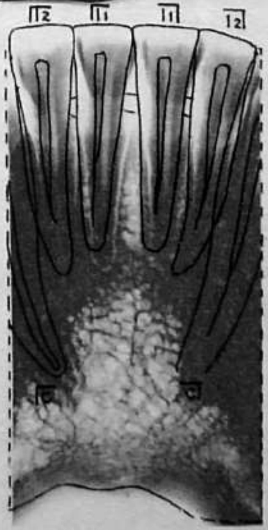
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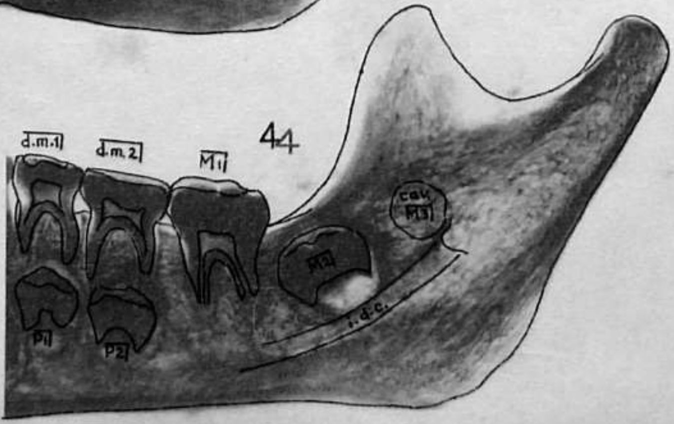
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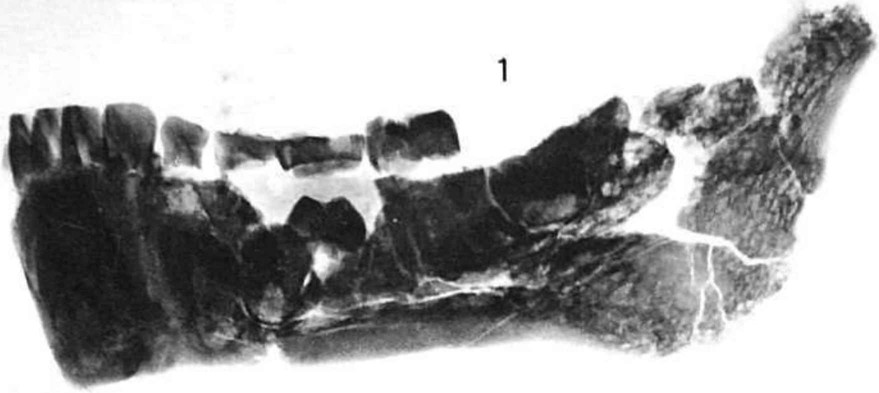

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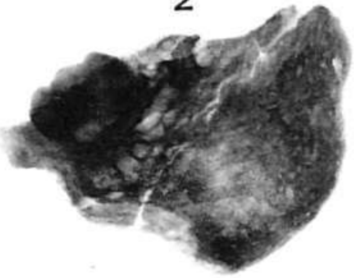

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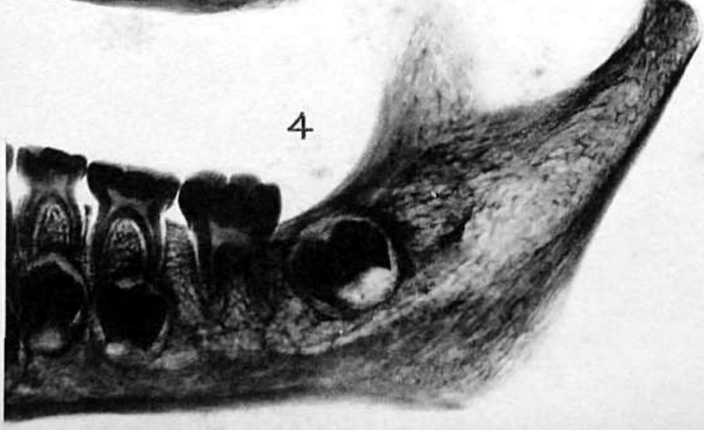

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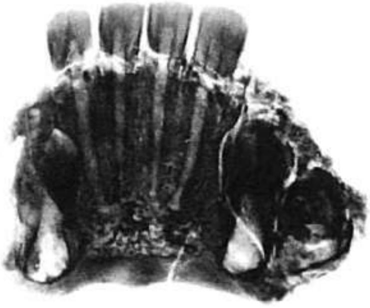

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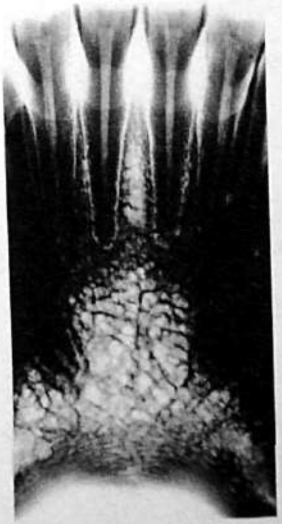

EXPLANATION OF

PLATE VII.

PLATE VII

Views of the fragment (left side and symphyseal part) of an adult female *Sinanthropus* mandible recovered from Locus H in 1935. *Sinanthropus* jaw H I. Natural size.

Figure 1 — labial view.
2 — lingual view.
3 — occlusal view.
4 — basal view.
5 — specimen viewed from in front.

(For posterior view of specimen confer Plate VIII, fig. 2).

None of the views correspond exactly to the alveolar plane orientation. For correctly orientated views the reader is referred to the respective textfigures.

Plate VII

EXPLANATION OF
PLATE VIII.

PLATE VIII

Figure 1 — Symphysis fragment of the *Sinanthropus* child mandible from Locus B (jaw B I) — see Plate II. Natural size.

Fragment viewed directly frcm below to demonstrate the tuber symphyseos and the digastric fossæ.

Figure 2 — Fragment of adult female *Sinanthropus* mandible H I. Posterior view. Natural size.

Figures 3 to 7 — Views of the fragment of the right side of *Sinanthropus* child mandible recovered from Licus B in 1928 and prepared in 1935 (jaw B IV). Natural size.

Figure 3 — labial view.
4 — lingual view.
5 — skiagram.
6 — occlusal view.
7 — view from the median plane.

Figures 8 to 13 — Views of the fragment of the right side of a *Sinanthropus* child mandible recovered from Locus B in 1928 and prepared in 1935 (jaw B III). Natural size.

Figure 8 — labial view.
9 — lingual view.
10 — skiagram
11 — view from the median plane.
12 — occlusal view.
13 — basal view.

None of the views correspond exactly to the alveolar plane orientation. For correctly orientated views the reader is referred to the respective textfigures.

PALÆONTOLOGIA SINICA

Weidenreich:—Sinanthropus mandibles

Plate VIII


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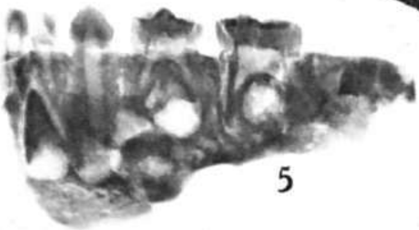
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EXPLANATION OF

PLATE IX.

PLATE IX

Figures 1 to 8 — Views of the fragment of the symphysis and adjoining parts of a *Sinanthropus* child mandible recovered from Locus B in 1928 and prepared in 1935 (jaw B V). Natural size.

Figure 1 — labial view of the symphysis.
2 — lingual view of the symphysis.
3 — skiagram of the symphysis.
4 — occlusal view of the whole fragment.
5 — basal view of the whole fragment.
6 — labial view of the right side.
7 — labial view of the left side.
8 — skiagram of the right side.

Figures 9 to 12 — Views of the fragment of the symphysis and adjoining parts of an adult *Sinanthropus* female mandible recovered from Locus H in 1935 (jaw H IV). Natural size.

Figure 9 — labial view of the symphysis.
10 — occlusal view of the whole fragment.
11 — basal view of the whole fragment.
12 — labial view of the right side and lingual view of the left side.

None of the views correspond exactly to the alveolar plane orientation. For correctly orientated views the reader is referred to the textfigures.


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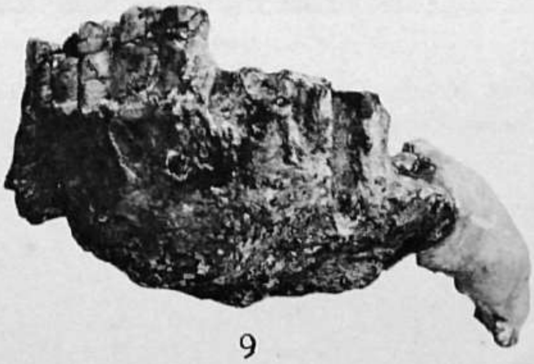
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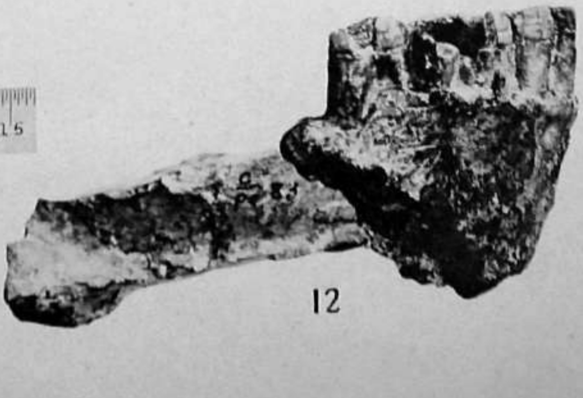
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EXPLANATION OF PLATE X.

PLATE X

Figures 1 to 6 — torus mandibularis.

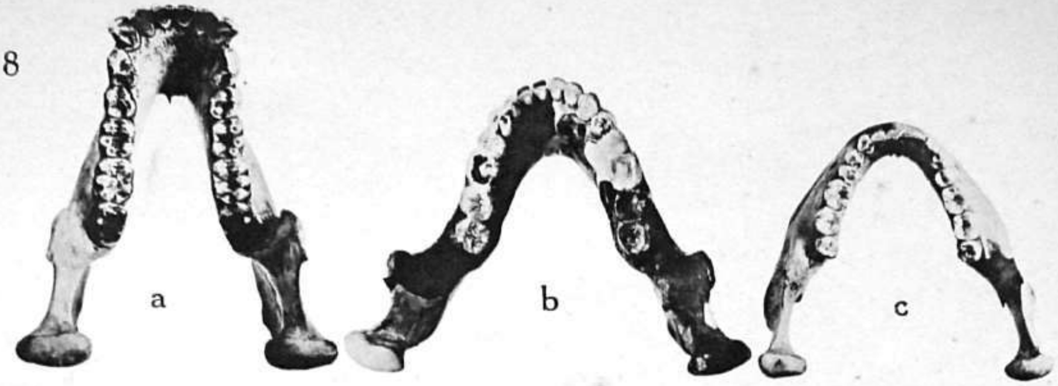
Figure 1 — torus of *Sinanthropus* male mandible G I. Natural size.
2 — torus of *Sinanthropus* female mandible H I. Approximately natural size.
3 — torus ("striation type") of *Sinanthropus* female mandible A II. Natural size.
4 — torus of a recent male North Chinese (140). Natural size.
5 — exaggerated type of torus of a Prehistoric Chinese (Yang Shao — Honan, No. 242/2).
6 — torus on both sides of a living individual American woman).

Figure 7 — Comparative profile views of the left sides of mandible of a female gorilla, No. 324 (a); male Sinanthropus G I, restored (b); and recent male North Chinese, No. 148 (c). 1/3.

Figure 8 — The same as in fig. 7 in occlusal view. 1/3.

Weidenreich:—Sinanthropus mandibles

Plate X



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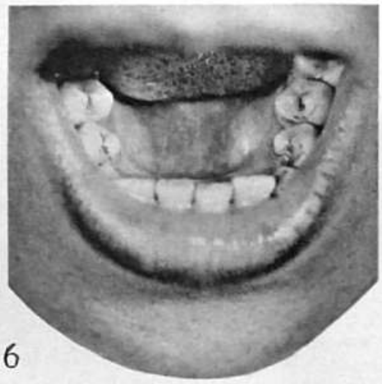

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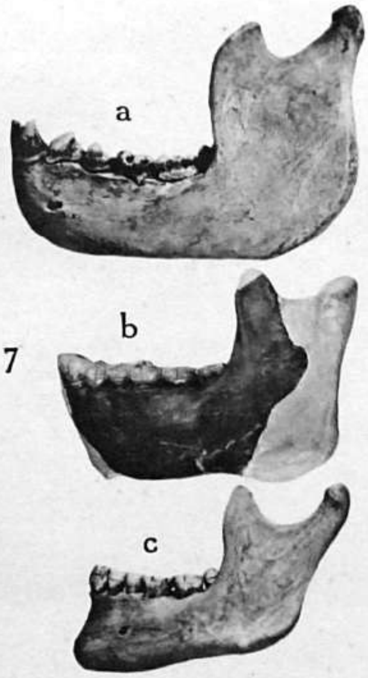

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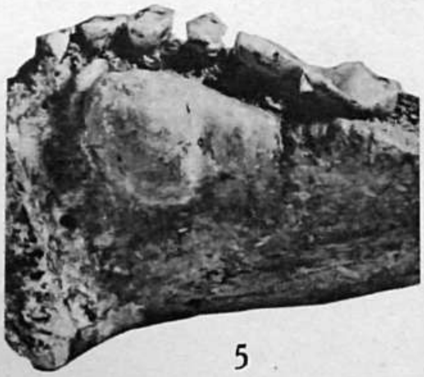

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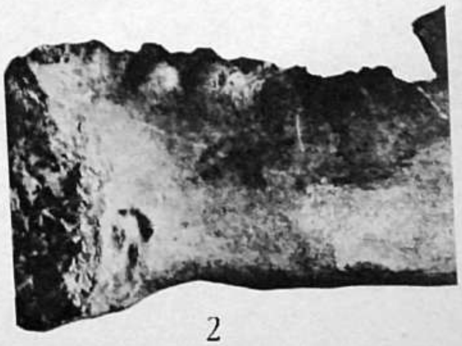

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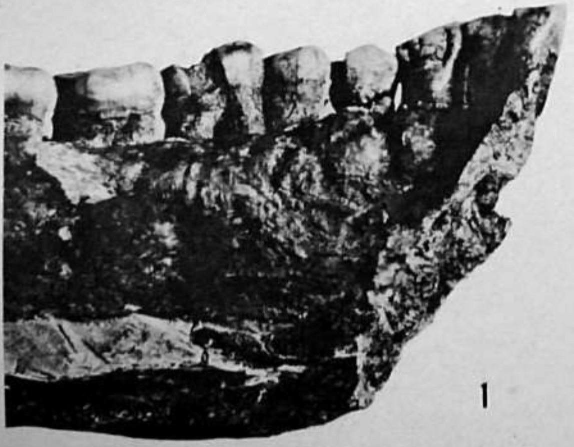

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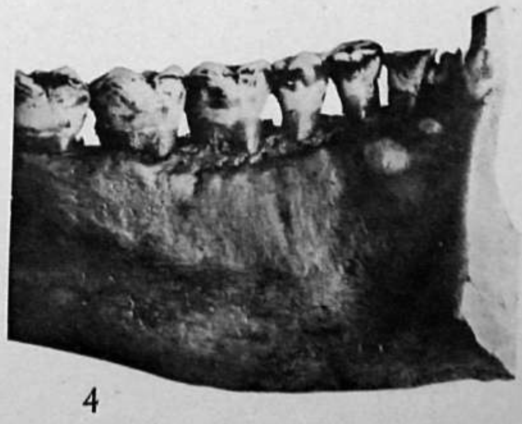

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EXPLANATION OF

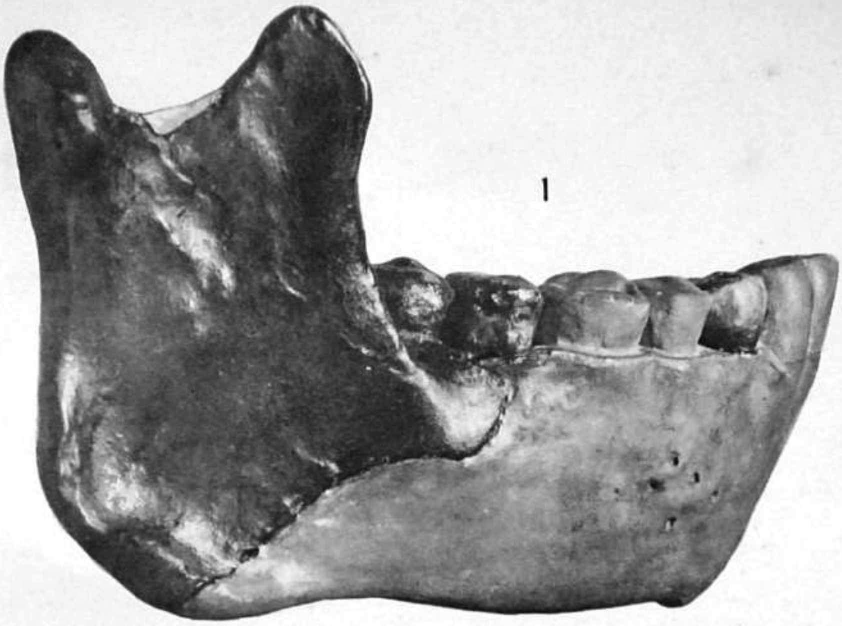
PLATE XI.

PLATE XI

Profile views (right side) in alveolar plane orientation of the restored *Sinanthropus* mandibles. Natural size.

Figure 1 — adult male *Sinanthropus* jaw G I. The partly restored left side is illustrated in Plate X, fig. 7 b.
2 — adult female *Sinanthropus* jaw H I.
3 — female *Sinanthropus* child jaw B I.

Orthogonal projections are given in the textfigures.



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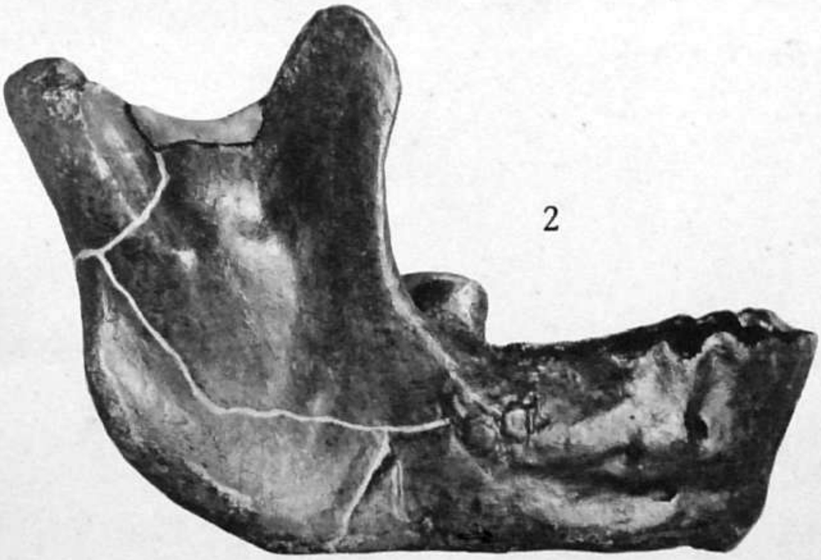

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EXPLANATION OF
PLATE XII.

PLATE XII

Figures 1 to 3. Occlusal views in alveolar plane orientation of the restored *Sinanthropus* mandibles. Natural size but not in orthogonal projection.

Figure 1 — adult male *Sinanthropus* jaw G 1.
2 — adult female *Sinanthropus* jaw H I.
3 — female *Sinanthropus* child jaw B I.

Orthogonal projections are given in the respective textfigures.

Figure 4 — Skiagram of the symphysis of the fragment (left side) of the adult male *Sinanthropus* jaw G I (compare Plate IV, fig. 1).


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EXPLANATION OF

PLATE XIII.

PLATE XIII

Basal views in alveolar plane orientation of the restored *Sinanthropus* mandibles. Natural size but not in orthogonal projection.

Figure 1 — adult male *Sinanthropus* jaw G I.
2 — adult female *Sinanthropus* jaw H I.
3 — female *Sinanthropus* child B I.

Orthogonal projections are given in the respective textfigures.


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EXPLANATION OF PLATE XIV.

PLATE XIV

Restored *Sinanthropus* mandibles viewed from in front in alveolar plane orientation. Natural size but not in orthogonal projection.

Figure 1 — adult male *Sinanthropus* jaw G I.
2 — adult female *Sinanthropus* jaw H I.
3 — female *Sinanthropus* child B I.

Weidenreich:—Sinanthropus mandibles

Plate XIV

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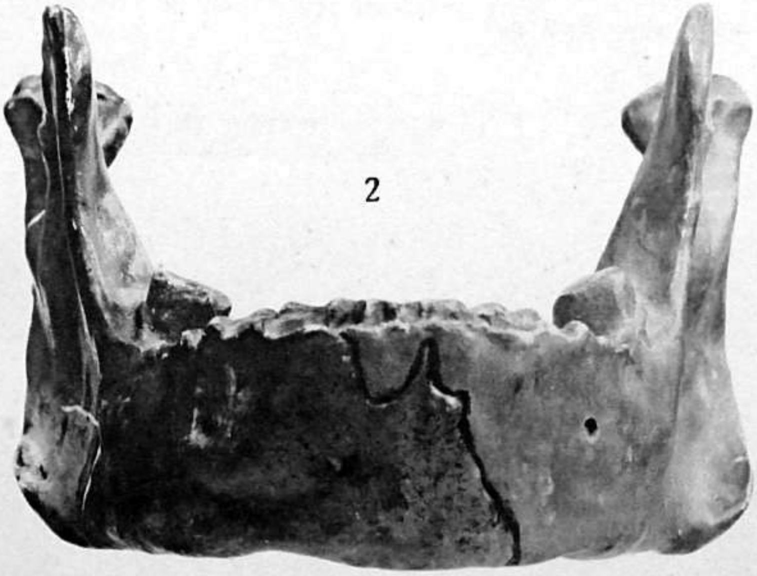

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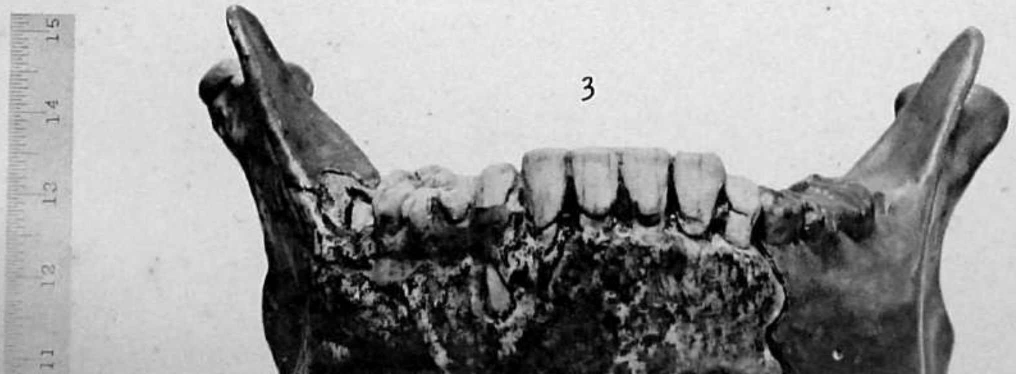


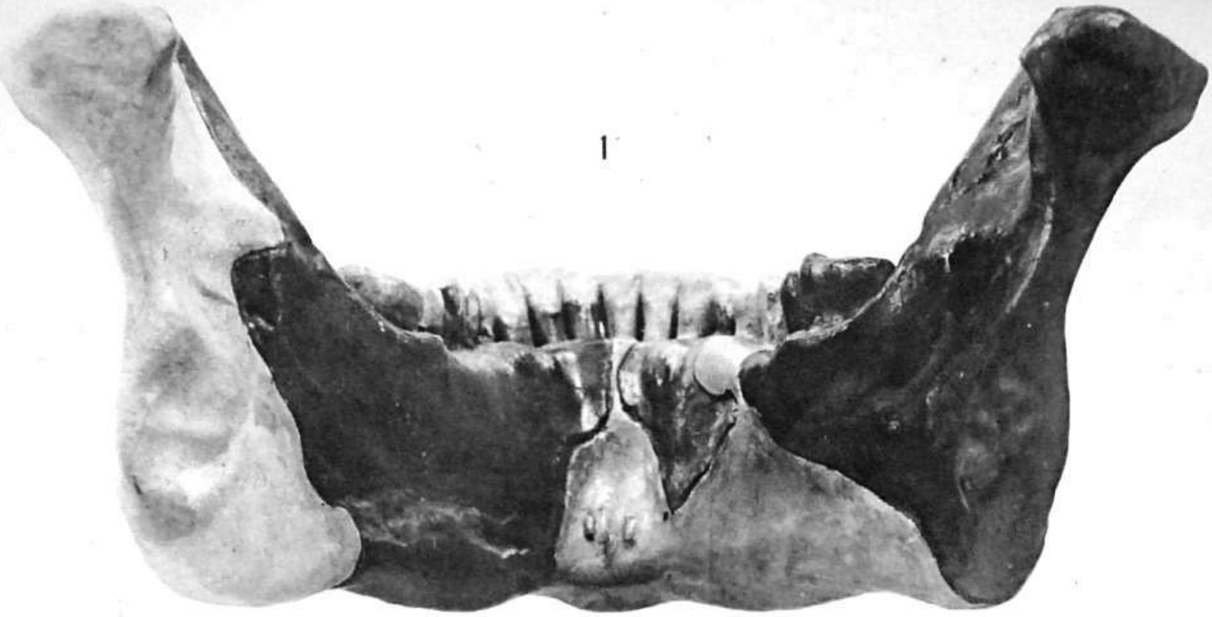
EXPLANATION OF

PLATE XV.

PLATE XV

Restored *Sinanthropus* mandibles viewed from behind in alveolar plane orientation. Natural size but not in orthogonal projection.

Figure 1 — adult male *Sinanthropus* jaw G I.
2 — adult female *Sinanthropus* jaw H I.
3 — female *Sinanthropus* child jaw B I.



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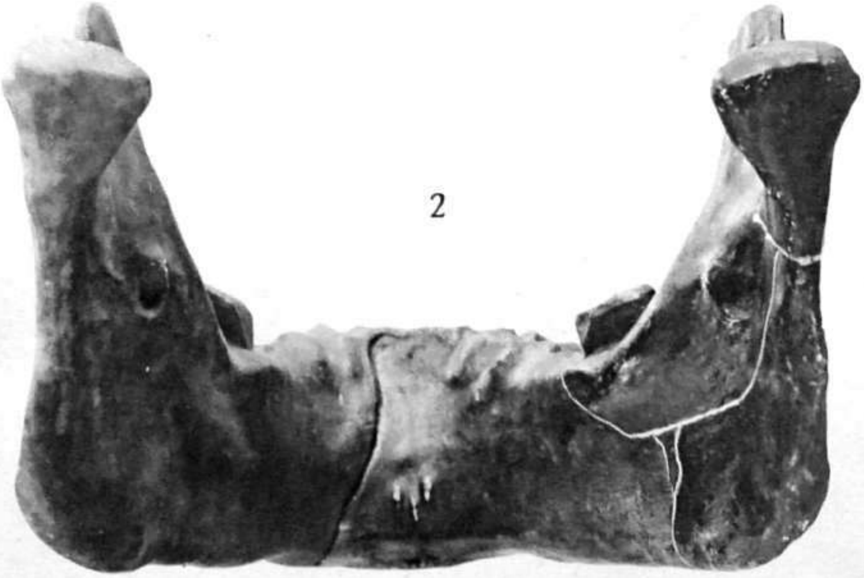

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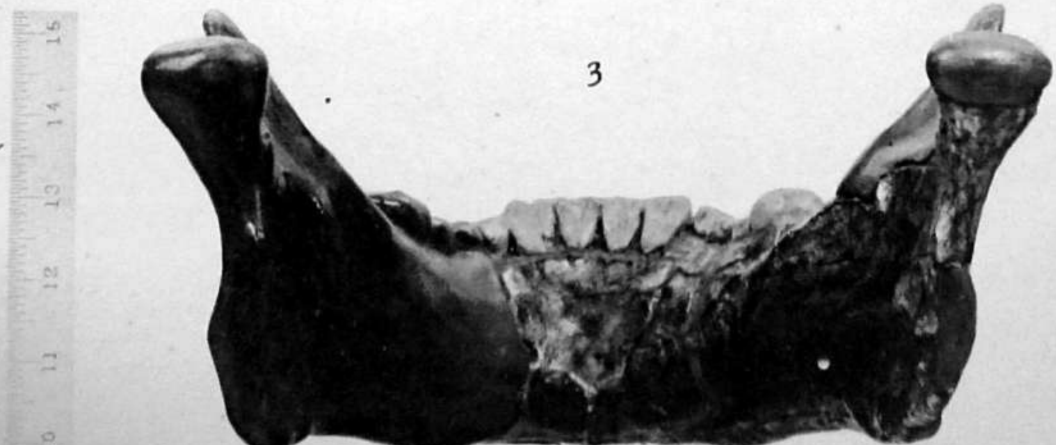

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