TAURODONT TEETH IN SOUTH AFRICAN RACES

By J. C. MIDDLETON SHAW, B.A., B.Dent.Sc. (Dublin)
Senior Lecturer in Dental Anatomy, University of the Witwatersrand, Johannesburg

CONTENTS

Introduction

In 1923 a number of remains, among them skulls and teeth, were discovered in two large rock-shelters at Zitzikama, Eastern Province, by Mr FitzSimons, Director of the Port Elizabeth Museum.

In the same year Prof. Raymond A. Dart pointed out the similarity existing between one type of skull discovered in the lowest levels of these rock-shelters and the Boskop remains.

In 1924 Dr Gordon D. Laing reported on the skulls (Strandlooper) from the higher and later levels of the same deposits at Zitzikama. Dr Laing concluded that the Strandlooper skulls showed a hybridisation of the Boskop race with the Bushman.

The teeth with which we are concerned are odd ones retrieved during the digging of these caves. They were received here unaccompanied by records of the skulls to which they belonged, but it is considered that the majority of them belonged to skulls of the superficial deposit, similar to those described by Dr Laing (i.e. Strandlooper skulls), and that two maxillary and two mandibular molars belonged to skulls from the lowest levels, similar to those described by Prof. Dart (i.e. Boskop skulls).

They were handed over to me by Prof. Dart for investigation and, for the reasons referred to above, they are described here as Strandlooper and Boskop teeth respectively.

Strandlooper teeth. A superficial examination of these odd teeth immediately revealed the fact that the molars (fig. 1, 1–4 and Plate I, *row A*) were markedly different outwardly from typical molar teeth of modern races, on account of the shortness of their roots and the relatively great length of their undivided portions, which must have been infra-alveolar when the teeth were present in their sockets (fig. 2, *A*).

The character of the chambers of some of these teeth, as revealed by sectioning on a revolving circular saw, afforded support to the view that these teeth differed greatly from typical modern teeth, for their pulp chambers were found to be relatively larger and to extend more deeply into that region of the tooth which in typical modern teeth is occupied by the roots (fig. 1, 1).

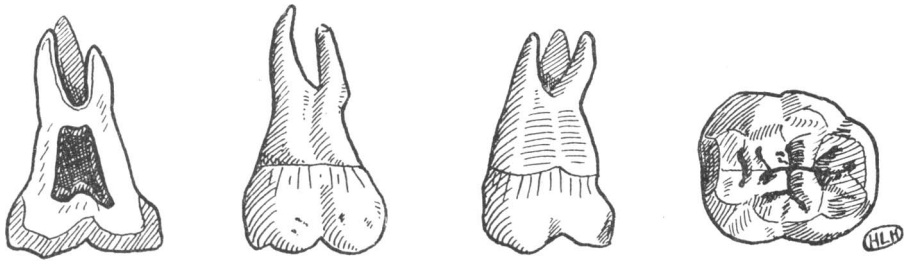


Fig. 1. Four typical examples of the molar teeth from Zitzikama.

Boskop teeth. These teeth were of the same general type as the Strandlooper teeth but were built on a larger and more generous plan (Plate I, *row B*). The roots of the lower molars are absent but the roots of the upper molars are present and exhibit a strong tendency to be fused into one solid mass. The relative size of the crown, root and undivided portion of these teeth is somewhat similar to the relative size of these parts in the Strandlooper molars.

Molar teeth with the characters found in these Zitzikama teeth, i.e. molar teeth with long infra-alveolar undivided portions, short or fused roots and relatively extensive pulp chambers, I had not seen formerly in any modern race (if infrequent third molar teeth are excepted). It is well known however that molar teeth with somewhat similar characters have frequently been discovered in fossil races (e.g. Neanderthal and Heidelberg).

In 1913 Sir Arthur Keith, writing on "Problems relating to the teeth of the earlier forms of prehistoric man," proposed that for "a curious process or condition of the molar teeth," i.e. "a tendency for the body of the tooth to enlarge at the expense of the roots," "we ought to have a distinctive name."

Provisionally, "for this condition or tendency" he proposed the name of "taurodontism," because, according to him, "the tendency for the body of the tooth to enlarge at the expense of the roots is a tendency to assume the

condition seen in the teeth of the ungulate or cud-chewing animals, e.g. the condition seen in the ox."

For "the opposite condition—that seen in the teeth of the carnivora—where the body of the tooth is above the alveolar margin," he proposed the name of "cynodontism."

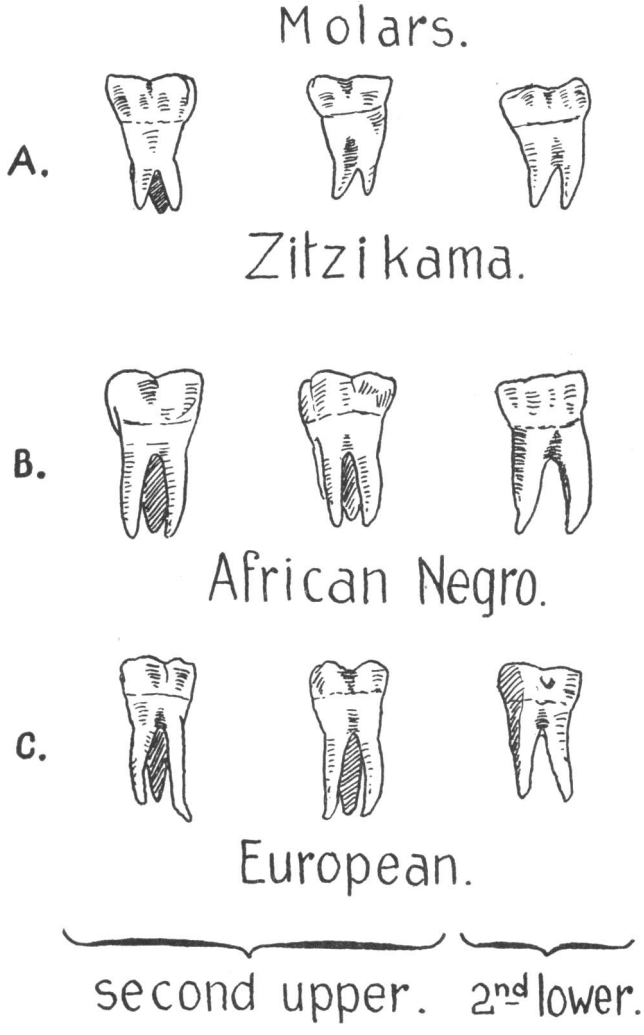


Fig. 2. Drawings of molar teeth of the Zitzikama peoples, African negro and European (natural size).

At a later date (1916) Sir Arthur Keith states that for "molar teeth" that "are large in crown and body and exceedingly short in root," he has "proposed the name of 'taurodont,'" and "to the more primitive form, seen in apes and also in modern types of men, the name 'cynodont' is given."

Accepting the terminology of Keith (1913) for this *tendency* in teeth, it is clear that the molar teeth discovered at Zitzikama exhibit "taurodontism."

Taurodontism, according to recent writers, is exceedingly rare in modern races, but occasionally, as pointed out by Keith himself, by Mummery (1923) and by other writers, third and other molar teeth are met with that show the condition. Kramberger (1907) has stated that the Eskimo sometimes exhibits a slight degree of taurodontism and Adloff (1910) has figured a taurodont tooth in a European.

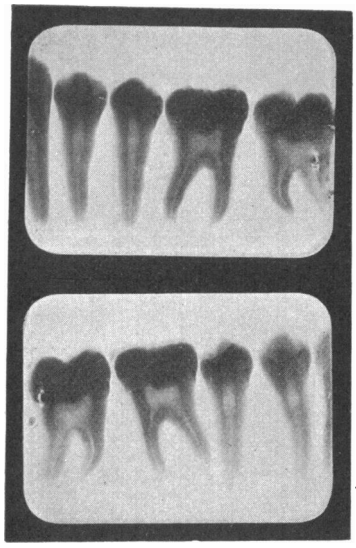
Taurodontism has been shown, as stated above, to be a character of certain fossil races (Heidelberg and Neanderthal).

The peculiar characters of the teeth in the Neanderthal race were described at length for the first time by Dr Paul Adloff (1908), who showed that the teeth of Neanderthal man, especially those discovered (1907) by Dr Gorganovic-Kramberger at Krapina, were long and infra-alveolar in their undivided portions, large in their crown, short or fused in their roots and possessed of very enlarged pulp chambers.

The name "taurodontism" was subsequently (1913) proposed by Sir Arthur Keith as the result of the necessity for introducing a term which would succinctly express this combination of characters. According to Keith (1916) taurodontism "is present to a greater or lesser degree in the teeth of all members of the Neanderthal race. It is a character of that race."

Many authorities, whose opinions will be stated more fully at a later stage, regard the "degree of taurodontism in the Neanderthal teeth" as a character of specific rank, i.e. a character which assists in demarcating Neanderthal man from modern (sapient) man. Unfortunately, these authorities have not stated, so far as I am aware, what "degree" of taurodontism they consider a character of specific rank, although the necessity for such a statement is evident since Keith has shown that the "degree of taurodontism varied widely in the examples of Neanderthal man so far discovered" (according to that writer the degree "was extreme" in a number of the teeth in the Krapina Neanderthaloids and "less marked" in the teeth found at Spy. Tomes (1923) states that "only 50 per cent. of the Krapina teeth presented peculiarities of the roots in any marked degree" and that the Spy molars could pass for molars of the modern type).

I have found it essential for the purposes of this communication to introduce more precise terms that will indicate the different "degrees" of taurodontism observed in the teeth examined by me. Accordingly it is proposed that the extent of vertical deepening of the undivided portion at the expense of the root seen in the teeth of the Heidelberg jaw ("a considerable degree," according to Keith (1916)) be taken as a mean; the extent of the development being known as "meso-taurodontism" and the teeth as "meso-taurodont teeth" (fig. 3, *C*). The extent of the development seen in the teeth of some of the Krapina Neanderthaloids (fig. 3, *D*) may then be denoted by the term "hyper-taurodontism," the teeth being called "hyper-taurodont



Skiagram 1. Skiagrams of the lower premolar and molar teeth of a Bantu-Boskop hybrid. (The third molar teeth are erupted but not shown in the skiagrams.)

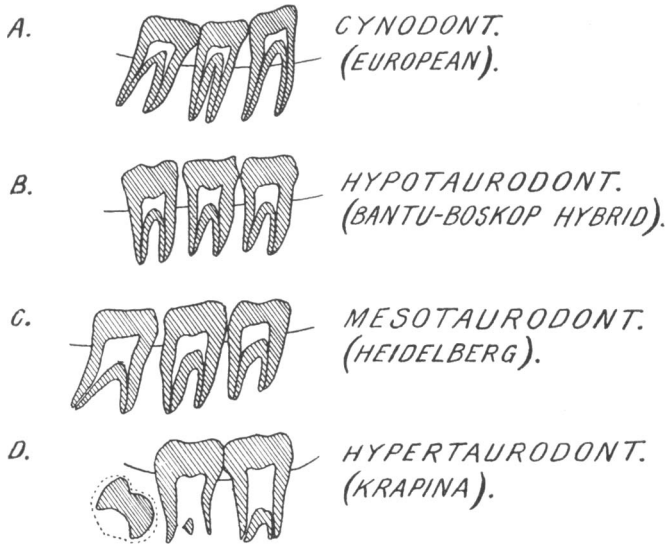


Fig. 3. Drawings from skiagrams of the lower right molars of modern European (*A*), Bantu-Boskop hybrid (*B*), Heidelberg mandible (*C*), Krapina mandible (*D*), to illustrate different degrees of taurodontism. ((*C*) and (*D*) after Professor Keith.)

teeth"; while the degree of development seen in the teeth of some South African Bantu-Boskop hybrids (fig. 3, *B*) may be called "hypo-taurodontism" and the teeth "hypo-taurodont teeth." Prof. Keith's terms, i.e. taurodontism and taurodont, with their opposites, cynodontism and cynodont, are still by this nomenclature retained as general descriptive terms for the tendencies exhibited by human teeth.

Although there is no doubt that the morphological characters of the Zitzikama teeth are not identical with those of the Neanderthal teeth, the presence of taurodontism in the molars from Zitzikama, and in molars of other South African people subsequently examined, warrants a detailed description of these teeth in this report.

Material

Unfortunately the skeletal material from Zitzikama had been returned to Port Elizabeth before taurodontism was discovered in the odd teeth. Hence a description of the teeth in the skulls is not possible at the present time.

The odd Zitzikama (Strandlooper) group consisted of seventy teeth. Fifty-seven of these are complete or partially complete teeth. Twelve are crowns (molar) of teeth. The remaining tooth has the characters of an ill-formed supernumerary premolar.

As stated formerly, the other odd Zitzikama (Boskop) group consisted of two maxillary and two mandibular molars, both appearing to belong to one individual.

Skulls utilised for examination of the teeth in other South African races were first of all those from a loan collection of Bush-Hottentot skeletons from the McGregor Museum of Kimberley[1]. Most of these skulls formed the basis of Dr R. Broom's communication (1925) to the Royal Anthropological Institute on the craniology of the yellow-skinned races of South Africa. They have been classified for the purposes of the paper by Mr H. S. Gear as follows:

1. Pure Bantu skulls ... ... 6 specimens
2. Pure Bush skulls ... ... 9 ,,
3. Bantu-Bush hybrid skulls ... ... 2 ,,
4. Bantu skulls showing Boskopoid element ... 5 ,,
5. Bush skulls showing Boskopoid element ... 3 ,,
6. Bush skulls showing Australoid (Broom) element 8 ,,

Total number of skulls in this collection: thirty-three.

In the second place, part of the extensive collection of skulls in the Anatomy Museum of this University was utilised. This collection has been classified as follows:

1. Bantu skulls ... ... 81 specimens
2. Bush skulls ... ... 6 ,,

[1] I am indebted to Miss M. Wilman, Director of the McGregor Museum, Kimberley, and also to the Trustees of that Institution, for lending this valuable collection of skulls.

3. Bantu-Bush hybrid skulls ... ... 5 specimens
4. Bantu skulls showing Boskopoid element ... 6 ,,
5. Bush skulls showing Australoid element ... 4 ,,

Total number of skulls in this collection: one hundred and two.

Finally, there were examined the dentitions in twelve skulls of known Bantu tribes. These twelve skulls are the property of the South African Institute for Medical Research and were lent to us by the Director, Sir Spencer Lister.

In all, therefore, the teeth in one hundred and forty-seven skulls were examined.

Remarks upon: 1. Dental Terminology. 2. Internal and External Characters as Criterions for the Diagnosis of the Conditions exhibited by Human Teeth. 3. Classification of the Characters of the Molar Series, as a whole, in a single Individual

1. *Dental Terminology*

According to Tomes (8th edit. 1923):

for the purpose of description the three external parts of a tooth are distinguished by name, viz. the crown, neck and root. This distinction is made in describing human teeth, and is applicable to the great majority of mammalian teeth, though there are some forms in which no such differentiation of parts can be seen. The crown is that portion which is exposed above the borders of the gum, and is in human teeth coated by enamel; the neck is that portion which corresponds to the edge of the gum, and intervenes between the edges of the bony sockets and the edge of enamel; the root is that part which is enclosed within the bony socket, and is covered by cementum.

Of these it is to be remarked that the "neck," although a convenient and necessary term for descriptive purposes, marks an arbitrary division of less importance than that expressed by crown and root; also that, although this division into three parts can be made in the case of socketed teeth of limited growth, no such distinction of parts can be made in teeth of perpetual growth.

According to the writings of Hopewell-Smith (1913), Mummery (1923) and others, Tomes' description of teeth, as quoted above, is correct. These writers recognise three parts of a tooth and define these parts in a manner similar to that adopted by Tomes.

In actual point of fact, however, where measurements of teeth are made, that portion of the tooth which intervenes between the crown and the root, i.e. the portion that Tomes and others call the "neck," is disregarded and the tooth is looked upon as consisting of crown and root only (*vide* Hopewell-Smith's *Dental Anatomy and Physiology*, p. 174 and following pages). This procedure, although loose, would be satisfactory enough if one had to deal only with cynodont teeth, where the intervening portion is small (approximately 2·5 mm.) in size and sufficiently short to be regarded as "arbitrary."

In taurodont molar teeth, on the other hand, Tomes' definitions, as quoted

above, cannot be applied because not only the roots but also a considerable part of the undivided portion of the tooth above the roots, although perhaps "not covered by cementum," nevertheless "is enclosed within the bony sockets" (*vide* fig. 3).

Further, with the great lengthening of the interval between the crown and the root the intervening part of the tooth can be no longer regarded as "arbitrary," but is on the contrary a striking and independent part of its anatomy and is, equally with the crown and the root, deserving of a specific descriptive term.

In applying a term to this middle portion of the taurodont molar tooth it is obvious that the term "neck," as defined by Tomes, is unsatisfactory, because in this type of tooth the middle part no longer "corresponds to the edge of the gum" and no longer "intervenes between the edges of the bony sockets and the edge of enamel." The term "body" has been used by Keith

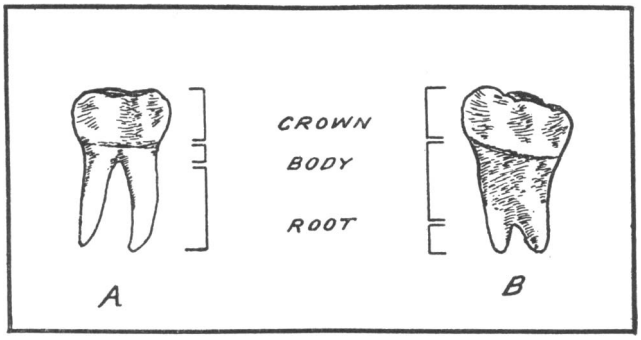


Fig. 4. Diagram to illustrate the parts of a cynodont tooth (*A*) and taurodont tooth (*B*), showing the measurements taken.

(1913) to describe this region and has found a certain currency in the literature, although he has in no place, to my knowledge, pointed out the necessity that exists here for the introduction of a new term, nor expressed clearly what the significance of the term "body," as used by him, actually is.

In this investigation it was essential to divide the taurodont molar tooth into three regions and to measure these regions separately (fig. 4). I have adopted as more suitable the term introduced without definition by Keith, to distinguish the middle portion of the tooth, namely, the *body*. I have further taken the liberty to define the *body* for the purposes of this report as that portion of the tooth which intervenes between the lower edge of the enamel and the upper end of the groove which usually marks the division or partial division of the roots and which seems to correspond with the uppermost extent of the cementum. Tomes' definition of the *crown*, i.e. that portion of the tooth which is exposed above the borders of the gum and is in human teeth covered by enamel, can be and is retained. The *root*, however, is defined

by me as the divided or partially divided portion of the tooth that is covered by cementum, is enclosed within the body socket and intervenes between the lower border of the body, as defined above, and the base of the bony socket.

The term *body*, so defined, may be applied to cynodont teeth, but even in these it does not necessarily correspond with the "neck" as defined by Tomes, and in view of the fact that the term "neck" as hitherto used by investigators *is* "arbitrary" and is usually entirely neglected in measurements taken, it is suggested that it should not in future be used for the purpose of anthropometric discussion (*vide* fig. 4).

It must however be remembered that the term "neck," as used by Tomes, while perhaps of no value anthropometrically, is of distinct value descriptively in another sense, namely, that while there is usually a very marked constriction at the junction of the enamel and cement in cynodont deciduous teeth, such a constriction is less marked in cynodont permanent teeth. Wherever the term (neck) is used in this paper it has reference to this character of constriction at the enamel-cement junction. Such a neck is also usually *absent* from taurodont teeth.

Following the definitions given above, the mean proportions of the crown, body and root lengths of cynodont (Bantu) maxillary molars (maxillary molars predominate in the Zitzikama collection) are 7, 2, 11 mm. of the whole respectively, i.e. the crown and root are long and the body is exceedingly short (fig. 4).

2. *Internal and External Characters as Criterions for the Diagnosis of the Conditions exhibited by Human Teeth*

Although it was primarily for external characters of teeth that the term taurodontism was proposed (*vide* statement of Keith given above), the size of the pulp cavity (i.e. internal characters), as revealed by radiographic examination, has been customarily taken as the basic criterion upon which the diagnosis of taurodontism has rested.

For this reason it is necessary to enquire whether internal or external characters afford the better criterion for the diagnosis of the conditions exhibited by human teeth.

Concerning internal characters it must be pointed out that, since the pulp is not a fixed organ, the "size and form of the pulp cavity are subject to manifold individual variations" (Loos, quoted by Hopewell-Smith, 1919).

It is relatively large in early life but decreases in size later in life, due to factors which are not as yet adequately known.

According to Campbell (1925) the decrease in size is due to *attrition*. The dentine being exposed, its fibrils are irritated and the odontoblasts stimulated to active formation of secondary dentine, which reduces the cavity size.

The investigations of Courtney Lyne (1916) on the formation of dentine, based on a very wide series of teeth at different ages, showed, according to

him, that the pulp cavity is reduced by *age*. That writer says that the pulp cavity, taking the average of one age with another, is steadily decreasing in size during life and that, *à priori*, a large pulp cavity indicates a tooth from a young animal and a small pulp cavity indicates a tooth from an older animal. It is also well known that a gradual change of the tooth-pulp into calcified tissue, as a result of *disease*, e.g. caries, and *injury*, proceeds to obliterate the pulp cavity and reduce its size.

Taurodont teeth are open to the same influences which reduce the pulp cavity in cynodont teeth. While, therefore, the presence of an enlarged pulp cavity may be conclusive proof of taurodontism, the absence of an enlarged pulp cavity is not necessarily proof that a tooth exhibits cynodontism. This fact is well known by some writers and Prof. Boule (quoted by Sollas, 1924) has in fact shown that the pulp cavities in some of the Neanderthal molars are exceedingly small; *even although the external characters of these teeth are of the taurodont type*. Hence, in the writer's estimation, internal characters, as revealed by radiographs, may be deceptive and may render nugatory conclusions based on these criterions alone. That is to say, internal characters, although admittedly of paramount importance as secondary or indirect evidence of the morphological characters of a tooth, are not in themselves conclusive evidence of the condition exhibited.

On the other hand, although no two dental organs possess exactly similar morphological characteristics, the external parts (crown, body and root) of any individual tooth, once formed, remain fairly constant in form throughout the life history of the tooth. The crown can, it is true, be worn away by attrition or disintegrated by caries; the body, as defined above, may be slightly altered by disease and the roots can be reduced slightly in size by absorption or enlarged slightly by deposition of cement. But, in its chief anatomical features, i.e. the relative proportions of crown, body and root, a tooth remains fairly fixed in external form during its existence. Moreover, in alteration of external form, it may be stated that the body, upon whose size the diagnosis of the condition of the tooth especially depends, is customarily the least affected of any by the above-mentioned factors.

As has been stated above, external characters afford adequate evidence for the diagnosis of the condition exhibited by some of the Neanderthal molars. Likewise, in this investigation it has been found that external characters and dimensions afford more reliable evidence of a tooth's morphological characters, whatever its age or however much it may be worn away, than internal characters. For example, it was found that the relative size of the parts—crown, body and root—of, among others, a second molar examined was 7 : 4 : 6 mm. respectively. The body of this tooth was long and infra-alveolar, the roots were short and fused, and yet the pulp cavity of this tooth was exceedingly small. That is to say, the external characters and dimensions betrayed the fact that this tooth was taurodont even although the internal characters afforded no indication whatever of this fact.

For these reasons the external characters of the teeth examined by me, as revealed by careful measurements and macroscopic examination, have afforded the basic criterion for the diagnosis of the conditions exhibited by these teeth.

3. *Classification of the Characters of the Molar Series, as a whole, in a single individual*

Although, as stated formerly, the external characters of an *individual* molar tooth remain fairly constant throughout the life history of that tooth, it is to be noted that in any *series* of molar teeth in a single individual the external characters (and internal characters) vary gradually from before backwards, i.e. in passing from the first to the third molar. In other words, if the second molar tooth is a typical meso-taurodont tooth the first molar is not so pronouncedly meso-taurodont, while the third molar is generally more markedly meso-taurodont and may tend towards a condition of hyper-taurodontism.

This general transition as we proceed from the front to the back of a molar series, and which I have never seen recorded, nor have ever witnessed personally, as progressing in the reverse direction, is due, as previously discussed, to factors of age, attrition and perhaps still further undiscovered causes.

Whatever the cause, it may be stated categorically that the first molar in any molar series tends less than any of the other molars to the condition of taurodontism and that the second and third molars tend more to the condition of taurodontism.

This fact is generally recognised and, as pointed out by Tomes (1923), some of the Krapina (taurodont) molar series afford excellent evidence of this transition in passing from the front to the back of a molar series (*vide* fig. 3, *D*). The same phenomena can be seen in radiographic pictures of the molar series in the Heidelberg jaw.

Although, however, the characters of the teeth in a molar series vary appreciably in this manner, it has been my uniform experience during this investigation to find that the condition exhibited by the molar series, as a whole, fluctuates around that exhibited by the second molar.

Thus, in all the dentitions examined, if the second molar was meso-taurodont the first and third molars were also meso-taurodont, even although the characters of the former tooth were inclined towards hypo-taurodontism and those of the latter towards hyper-taurodontism. Likewise, where the second molar was hypo-taurodont the first and third molars were hypo-taurodont, although definitely exhibiting the character to a lesser and greater degree respectively than the second molar.

Owing to the fact that the condition of the molar series as a whole fluctuates around that exhibited by the second molar, it is convenient, for the purposes of classification of any molar series *as a whole*, to accept the second molar tooth as the standard tooth upon which to base the diagnosis of the

condition of the series. Accordingly, in this report, the second molar has been accepted as the standard tooth of the series and the terms hyper-taurodontism, meso-taurodontism, hypo-taurodontism and cynodontism have special reference to the type of the second molar in the dentitions examined.

Stated briefly, the conclusions arrived at are the following:

1. A tooth consists of three parts, namely, a crown, a body and a root.
2. A cynodont tooth has a relatively long crown and root and a relatively short body.
3. A taurodont tooth is relatively long in crown and body and relatively short in the root.
4. Internal characters of a tooth, although of considerable service as secondary or indirect evidence of the morphological character of the tooth, are not in themselves conclusive evidence of the condition of the tooth.
5. The external characters of a tooth and the relative proportions of its crown, body and root, as revealed by macroscopic examination and careful measurements, afford the best criterion for the diagnosis of taurodontism or cynodontism.
6. The characters of the molar teeth in a molar series in a single individual fluctuate around those exhibited by the second molar tooth. The second molar tooth in a molar series may therefore be taken as the standard tooth of that series for the purpose of classification of the characters of the series as a whole.

Zitzikama Strandlooper Anterior Teeth

The majority of these teeth conform to the Bantu type but a few differ slightly from that type.

Thus, one second maxillary incisor and two maxillary canines exhibit well-marked marginal ridges on their lingual surfaces, which produce a roughly triangular shallow concave central fossa on this aspect of the teeth. Teeth with the same characters, according to Hrdlička (1920), "occur frequently in yellow-brown peoples, such as Malays, Mongolians, Chinese and Japanese but are less common to rare in other racial groups." Because they "resemble more or less an ordinary coal shovel" they are termed by Hrdlička "shovel-shaped teeth." That writer recognised three grades of "shovel shapes" in the teeth examined by him and adopted the term "shovel" for all the better developed grades; "semi-shovel" for the less well-developed grades and "trace-shovel" for slight but distinct indication of the character.

Accepting this terminology, the Strandlooper maxillary canines are "semi-shovel"; the incisors are "trace-shovel."

Four first maxillary incisors are also of interest because the lines which represent their proximal surfaces converge rapidly towards the necks. In other words, these teeth exhibit marked excess in their transverse diameters at their biting edges.

Azoulay and Regnault (1893) have stated that this character is not infrequently found "in inferior races" and rarely found in "the yellows, the

European and Hindus." Leon Williams (1914), on the contrary, although expecting to find racial differences in the form of the incisors, found that no such differences existed and that "three primary forms of teeth are common to all races."

Examination of the teeth in South African Bantu races afforded support to Leon Williams' view, for it was found that in these races three forms of upper first incisor teeth may be recognised. It must be pointed out, however, that it has been my experience to find that the form of incisor tooth described above (Class II, of Williams) is the rarest form in typical South African Bantu races. That is to say, the type of incisor tooth discovered at Zitzikama is not identical with the typical type of incisor tooth found in living Bantu races.

Zitzikama Strandlooper Molars

Fourteen complete molars (three of which are lower molars) and twelve molar crowns (four of which are the crowns of lower molar teeth) were found in the Zitzikama Strandlooper collection.

The Complete Teeth. One of the complete lower molars and four of the complete upper molars are, unfortunately, third molar teeth and it was decided that these should not be described in detail (on account of the variability in size and shape of such teeth in all races). It is to be noted, however, that these third molars belong to the same general type and exhibit the same characters in the same or even a more marked degree than those now to be described

1. *External Characters.* The complete molars (seven from the upper and two from the lower jaw) are, with three exceptions (two upper and one lower tooth), exceedingly small in all respects. The average mesio-distal length of the crown of the five small maxillary molars is only 9·6 mm., the average bucco-lingual width is 10·5 mm. (*vide* fig. 5) and the average (extreme) length, from the apex of the lingual root to the most prominent part of the mesio-lingual cusp (which is slightly worn in all cases), is approximately 17·0 mm.

The dimensions of the remaining two maxillary molars do not differ greatly from those of modern Bantu races.

The five maxillary molars referred to above are remarkable, however, not only in their actual smallness, as compared with typical (Bantu) human teeth, but also in the shortness of their roots relative to the length of their crowns and in the large size of their bodies; in other words, in the relative growth of their bodies at the expense of their roots (fig. 2). Thus, the average length of the lingual root of the five teeth is only 7·0 mm., the average length of the crown (slightly worn) 6·0 mm., and the average length of the body 5·1 mm.

The relative proportions of crown, body and root of the remaining two maxillary molars are approximately similar to those of these five teeth.

The proportions of the crown, body and root of the Strandlooper maxillary molars are therefore approximately 6 : 5 : 7 mm., the extremes being

6 : 6 : 7 mm. and 6 : 4 : 7·5 mm. That is to say these teeth, compared with cynodont (Bantu) teeth, have slightly smaller crowns; bodies that are relatively and actually larger, and roots that are relatively and actually shorter, than those of cynodont Bantu teeth.

The constriction or "neck" at the junction of the enamel and cement varies from being ill defined to being entirely absent.

The external characters, dimensions and relative proportions of the crown, body and root of one of the lower molars in this collection are similar to those of the upper five maxillary molars, while the other lower molar is a much larger tooth and exhibits the character of fusion to a marked degree. The relative proportions of its crown, body and root are approximately 7 : 8 : 5 mm. respectively.

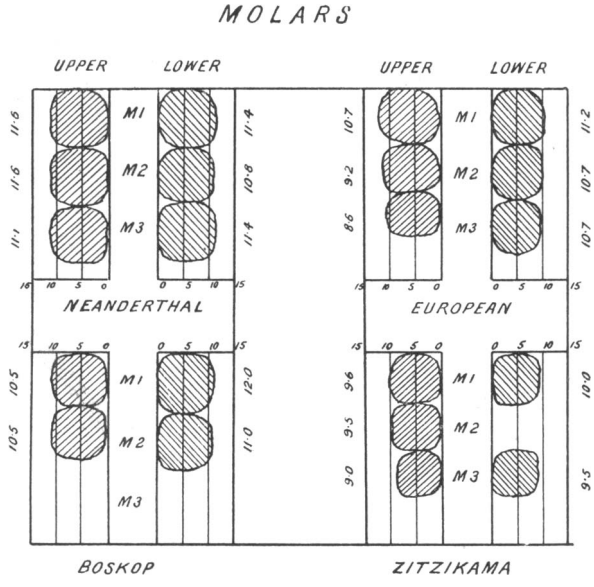


Fig. 5. Diagram showing the development of molars in Neanderthal, European, Boskop and Zitzikama man; the teeth are placed in the diagram so as to contrast their lengths or mesio-distal diameters. The parallel lines which cross the length of the crowns are 5 mm. apart. (Neanderthal and European man after Campbell.)

Consequently, as far as the outer aspect is concerned, taurodontism is exhibited by these Strandlooper molars. I consider that these teeth are entitled to be placed in the meso-taurodont class, as defined above.

2. *Internal Characters.* In two instances the internal characters of the Strandlooper molars were revealed by sectioning and the internal characters of the remaining teeth were revealed by radiographic examination.

Although, as stated formerly, the pulp cavities in the majority of these teeth are relatively large, actually they are not larger than the pulp cavities of adult cynodont (Bantu) teeth, except in two instances.

One, an upper first molar with its root apices not yet completely closed, has a pulp cavity which measures 5·0 mm. in the bucco-lingual direction, slightly less in the mesio-distal direction, and 6·0 mm. in the vertical direction.

Another upper molar, a second probably, has a pulp cavity that measures approximately 4·5 mm. in all directions. This tooth is well worn and possibly belonged to an individual of much more than adult years. The remaining teeth have pulp cavities that vary in size. In two instances the cavity is considerably reduced in size by deposit of secondary dentine. In the other teeth the cavity in no instance exceeds 3·5 mm. in diameter, but in these teeth also there is evidence of deposit of secondary dentine.

From this it is concluded that in the teeth of younger individuals of the Strandlooper race the pulp cavities must have been considerably larger than in the worn and, in many cases, aged specimens described here.

The Crowns. The molar crowns require no detailed description. Their occlusal surfaces do not differ greatly from those seen in recent negroid races except that four lower molar crowns exhibit crenation or wrinkling of their enamel (fig. 1, 4). This condition I had not seen previously in any *adult human* teeth nor do I know of any instances recorded in European or Bantu races. Gregory (1921) has stated, however, that "lower molar crowns with wrinkled surfaces" are found in Bush peoples, and Boule (1923) has stated that the (taurodont) Taubach molar tooth (described by Nehring, 1895) exhibited the same condition. I regret that the Bush material available for study in this Department lends no support to Prof. Gregory's statement and it therefore appears probable that *even in Bush peoples crenation of the enamel is an exceedingly rare condition.*

Many of the lower molar "crowns" in this group possess five cusps and are larger than the crown of the small complete lower molar referred to above. Likewise, a few of the upper molar "crowns" are as large as the crowns in Bantu races, but the majority do not differ in their dimensions from the crowns of the small Strandlooper maxillary molars.

Since the roots and bodies are absent, there is nothing to indicate that these "crowns," as well as the "complete teeth," are not crowns of meso-taurodont teeth. The resemblance in form and size of some of them to the crowns of the complete teeth and the fact that they were discovered in the same deposits at Zitzikama as those, appear to warrant their inclusion in the same meso-taurodont group.

We may conclude therefore that meso-taurodont teeth occurred with considerable frequency in the Strandloopers, which are known to be Bush-Boskop hybrids (Laing, 1924).

Zitzikama Boskop Molars

It was evident on inspection that, although these teeth possessed the same general characteristics as the Strandlooper teeth, they were markedly larger in all their dimensions and slightly different in some of their anatomical

features (Plate I, *row B*) (fig. 6). The two maxillary molars (one, a first molar, the other, a second molar) are most remarkable. They exhibit complete fusion of their mesio-buccal and lingual roots, thickening and enlargement (not elongation) of their disto-buccal roots and overgrowth of their bodies.

It must be noted, however, that the fusion of their roots is not due to an approximation of the roots—the result of retrograde development—but is due rather to an opposite process, namely, an extension of the body of the tooth into that region which in cynodont teeth is occupied by the roots. That is to say, the roots of these teeth were never distinct to become fused later; the joined condition is one of initial development, brought about by a downward extension of the tooth body at the very earliest stage of its development.

The dimensions of their crowns are greater than those of the crowns of many Bantu molar teeth (*vide* fig. 5). The relative proportions of crown, body and root it was found impossible to ascertain with any degree of accuracy, owing to absence of fragments of the teeth at the junctions of these parts.

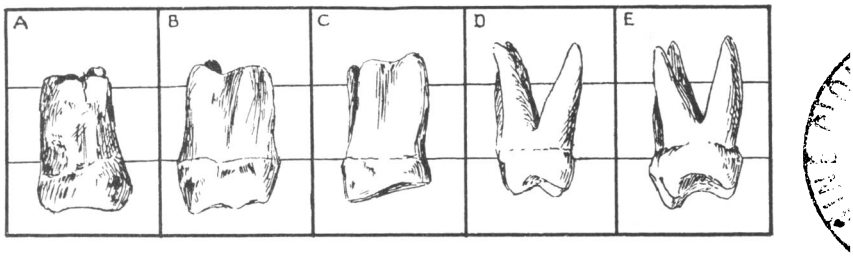


Fig. 6. Mesial aspect of upper molars of Neanderthal man (*A*); Zitzikama man (*B*); Boskop man (*C*); European man (*D*); and Chimpanzee (*E*). (Natural size.)

There is, however, no doubt that the crowns and bodies are relatively larger and that the roots are relatively and actually shorter than those of cynodont teeth (*vide* fig. 4).

Although these two Boskop maxillary molars are not as markedly hyper-taurodont as some of the Krapina molars, I consider that their characters entitle their inclusion in the same hyper-taurodont class, and accordingly they may be termed hyper-taurodont teeth.

The two lower molars lack their roots, but it is evident from inspection that when these were present they were not fused but divergent.

These teeth are also of large size (fig. 5) and their crowns each possess five cusps and are longer in the mesio-distal than in the bucco-lingual directions. Their bodies and pulp cavities are slightly larger than those of typical Bantu teeth.

For these reasons it is considered that these teeth probably exhibited the condition of hypo-taurodontism. The conclusion is therefore warranted that hyper-taurodont and hypo-taurodont teeth occurred in South African Boskop races.

Taurodont Molar Teeth in other South African Races

It was desired to ascertain: (1) whether taurodont teeth occur in living South African races, (2) whether the condition of taurodontism appears in as marked a degree in living South African races as in the teeth of the Zitzikama peoples described above.

The entire collection of skulls utilised for this investigation has been detailed earlier in this paper. Collectively, they fall naturally into four main groups:

1. Bantu group.
2. Bush group.
3. Korana group (Australoid of Broom).
4. Bastard group.

The dentitions of these skulls were not absolutely complete, for teeth had been lost, not only before death but also post-mortem. The cheek teeth, however, are present in one or both sides of the upper or lower jaw in all the skulls examined. Further, in the case of teeth lost after death, the condition of the socket was usually found to afford adequate evidence of the external characters of the body and root of the absent teeth. The age of the skulls and dentitions vary, but in all cases it is considered that the individuals to whom these skulls and dentitions belonged had attained at least adult years.

All observations on the teeth were carried out with the aid of radiographic (indirect) examination (*vide* skiagram 1), but, as stated formerly, macroscopic examination and careful measurements of the crown, body and root afforded the basic criterion for the diagnosis of taurodontism.

Table I. *Showing the occurrence of taurodontism in South African races*

Race	Number of Skulls	Hyper-Taurodont Skulls	Meso-Taurodont Skulls	Hypo-Taurodont Skulls	Cynodont Skulls	Percentage of Taurodont Skulls	Percentage of Cynodont Skulls
Pure Bantu	99	0	0	0	99	0·0	100·0
Pure Bush	15	0	0	0	15	0·0	100·0
Bantu-Bush hybrids	7	0	0	0	7	0·0	100·0
Bantu with Boskopoid element	11	0	3	1	7	36·3	63·6
Bush with Boskopoid element	3	0	1	0	2	33·3	66·6
Bush with Australoid (Broom) element	12	0	3	2	7	41·6	58·3
Totals ...	147	0	7	3	137	6·8	93·7

Diagnosed in the manner stated above, taurodontism was found to occur in the teeth of living South African races. Classified on the basis of the second molar tooth, the extent to which the condition was developed and the frequency of occurrence of the condition in the dentitions examined is shown figuratively in Table I.

It will be seen from that table that taurodontism appears in as marked a condition in living South African races as it did in Zitzikama peoples. Further, it will be seen that taurodontism is absent from the teeth of pure Bantu and Bush peoples and also from the teeth of Bantu-Bush hybrids. The pure Bush and the pure Bantu stocks must therefore be cynodont.

On the other hand, in bastards, where the elements of fusion are Bantu or Bush with Boskopoid or Australoid peoples, taurodontism occurs with some degree of regularity—roughly in 30 per cent. of the bastards examined.

Where the elements of fusion are Australoid and Bush the condition occurs slightly more frequently than where the elements of fusion are Boskop and Bush or Boskop and Bantu. There is, however, evidence from this incidence to demonstrate that taurodontism was a feature of both the Boskopoid and Australoid peoples of Southern Africa.

We may conclude that:

1. The Bantu and Bush peoples of Southern Africa possess teeth of the cynodont type.

2. Taurodont teeth are, however, found in living South African races.

3. The condition of taurodontism is developed to the same extent in living South African races as in the teeth of the Strandlooper and Boskopoid peoples from Zitzikama.

4. Taurodontism occurs in South African hybrids where the elements of fusion are Australoid or Boskopoid with cynodont types like the Bantu or Bush races. Taurodontism is therefore a character of South African Australoid and Boskopoid peoples.

5. Taurodontism occurs roughly in 30 per cent. of such hybrids and therefore appears to act as if it were a Mendelian recessive character in the proportion of its emergence in hybrid stocks.

6. Taurodontism appears to be a character which breeds true in the Mendelian sense and therefore must be a character of at least *variety* rank.

7. Since taurodont races can intermingle with cynodont races of mankind and produce fertile offspring, taurodontism is not a character of zoological *species* rank.

8. Races which equal one another in a character demonstrated to be of *variety* rank are probably more closely related to one another than those not exhibiting the character.

9. The South African Australoid and Boskopoid peoples are more nearly related to one another than either people is to the Bantu or Bush stock. Inversely, the Bantu and Bush races are more nearly related to one another than either race is to South African Australoid or Boskopoid peoples.

The Significance of Taurodontism

As of late years many inferences have been based upon taurodontism in the teeth of fossil man, the occurrence of taurodont teeth in modern races warrants an inspection of the significance of any new facts emerging from such a study as the present one.

In Neanderthal man the occurrence of taurodont teeth has been used as an argument that recent man cannot have descended from that race of man but belongs to a separate stock which in early times supplanted Neanderthal man, who died out.

The opinion that the taurodont teeth of Neanderthal man do not represent a stage in the evolution of modern cynodont teeth was first advanced by Adloff (1908), who considered that the *degree* of taurodontism exhibited by the teeth of that race was a specialised or retrograde character, not a primitive feature. Keith (1913), after entertaining the contrary view (1908), has now become a convert to the idea that taurodontism in the Neanderthals is a specialised character. According to him, taurodontism takes the Neanderthal race away from the ancestral line of modern man.

Gregory (1921), however, considers that "at least a moderate degree of taurodontism is a primitive feature for the Hominidae" and that the taurodont teeth of Neanderthal man, or some of them, may be structurally ancestral to teeth of the modern cynodont type.

Although it has been stated that taurodontism is the opposite to what obtains in anthropoids and primates generally, it is a remarkable fact that data concerning the external characters and relative sizes of the crown, body and root of molar teeth in primates other than man are either inaccessible or non-existent. That is to say, there is no evidence to prove that taurodontism, diagnosed by external characters and dimensions as suggested here, is never a character of the dentitions in at least some branches of the anthropoids.

Further, even if it be demonstrated that taurodontism does not occur in modern anthropoids, if Prof. Gregory (1920) and Prof. Miller (1915) are correct in assigning the Taubach molar to a fossil Pleistocene chimpanzee, there is evidence that taurodontism is known in the teeth of some *fossil* members of the anthropoid group. The Taubach molar has been figured by Keith as an example of a taurodont tooth with the "Neanderthal characters," and there appears to be considered evidence in favour of the view that this tooth belongs to no known member of the human family.

It has never been shown conclusively that the condition of taurodontism is not a primitive feature for anthropoids and, even if it had been so shown, since the anthropoids are themselves probably specialisations from the primate stem, the absence of taurodontism from the teeth of the living representatives of this group does not warrant the conclusion that taurodontism is a specialised character for the Hominidae.

When we come to examine the teeth of primitive man we find that the

teeth of Pithecanthropus (possibly the oldest human fossil known), although perhaps definitely of the cynodont type, are known to be highly specialised and therefore not available for comparison here.

The teeth of Eoanthropus, according to Gregory (1921), possess "a pulp cavity that is deeper than is common among modern teeth" associated with primitive features of the jaw and dentition. The relative proportions of crown, body and root have not, so far as I am aware, been published, but, from the condition of the pulp cavity, it appears not improbable that some degree of taurodontism is exhibited by the molars of the fossil.

In Heidelberg man who, it has been suggested, is a pre-Neanderthal, the teeth are likewise of the taurodont (presumably meso-taurodont) type, even although the crown patterns of the teeth and many of the characters of the jaw are of admittedly primitive human type.

In the Neanderthals taurodont teeth are also of frequent occurrence. In that race also, taurodontism is found associated with primitive features of the dentition, and although some writers claim that all the teeth exhibited taurodontism, the available records show that this was not the case. According to Tomes (1923) only 50 per cent. of the Krapina teeth were markedly affected by the condition and the molars of the Spy skulls could pass for molars of the modern cynodont type. Kramberger's work (1907) shows Neanderthal teeth with quite distinct and lengthy roots and bodies of the cynodont type. That is to say, the teeth of the Neanderthals varied from teeth of the massive taurodont type to teeth that cannot be distinguished from cynodont teeth.

This variation would find a natural explanation from the facts brought forward here if we regard the Neanderthals as a bastard race—taurodont Neanderthals uniting with a cynodont people to produce a mixed offspring, or taurodont pre-Neanderthals (? Heidelberg) uniting with a cynodont people to produce mixed Neanderthals.

However that may be, it is evident that the condition of taurodontism has occurred over an immense period of time and is not, so far as the present records show, absolutely distinctive of one particular race only. It is possible that the teeth of fossil apes (the Taubach molar) exhibited the condition. Eoanthropus also may possibly provide an example of the character and there is no doubt that the teeth of Heidelberg man and of many of the Neanderthals exhibited the condition of taurodontism to a marked degree.

It has been stated that in modern races the pulp cavity is relatively larger in teeth of young persons than in the teeth of adults and that this relatively large pulp character as an infantile condition is the persistence of a character that is primitive for the Hominidae.

So far as the size of the pulp cavity is concerned, there is little doubt that teeth at an early age, not only in man but also in primates generally, do exhibit the condition of taurodontism to a more marked degree than do the teeth of adults.

It appears possible therefore that this infantile character does signify the

persistence of a primitive feature. In any case, as has been stated formerly, the condition of taurodontism is known to occur even in the teeth of *adult* modern individuals. The condition has been stated to occur in modern Europeans (Adloff figured a taurodont molar in a modern European, 1910, Plate X, Jaw *H*), in Mongolians (the Eskimo, according to Kramberger) and is definitely present in South African races, including Australoid peoples.

From the occurrence of taurodontism, and the association of very primitive characters with taurodontism, in apes from early Pleistocene times, in primitive human fossil races from the earliest chapters of our history, in the developing teeth of primates generally and in the teeth of adults of many modern races, it appears that there is considerable support for the view that taurodontism is a primitive character.

If taurodontism is a primitive character it is evident that all taurodont races have sprung from one stock and that all cynodont races are offshoots from this taurodont type.

Whether taurodontism is a primitive feature or not, we must believe that either all taurodont races have sprung from one stock or that there has been convergent evolution at different geological stages in human history.

Although many authorities consider that the taurodont Neanderthal race represents a side branch of the human race which became wholly extinct in western Europe, other authorities (e.g. Hrdlička, 1914) state that Neanderthal characters are met with in individuals in Europe in periods later than the Palaeolithic and even in present-day populations, and that such characters should be regarded as atavisms showing reversion to that ancient race. That is to say, it has been stated that traces of Neanderthal blood and physiognomy are not lacking even in modern Europeans and that such characters, and evidently the characters of taurodontism also, should be regarded as atavisms showing reversion to the Neanderthal race.

This is a question which obviously needs further investigation by scientists in Europe. We do not know what the fate of the Neanderthal race in Europe was, but it is possible that analysis of the incidence of taurodontism in Europeans may yet reveal that fate. In other regions, e.g. Africa, it is possible that this race or some closely allied taurodont group has survived into a later epoch and is responsible for the character of taurodontism here.

The discovery of the condition in living South African races and in other races widely separated geographically certainly indicates, in the writer's estimation, that we may have to admit that these characters, thus placed in parallel, are not convergent but derivative. Until convergence can be demonstrated it certainly seems preferable that the character of taurodontism be regarded as primitive and the people possessing taurodontism as having come from one stock. In other words, dental comparisons indicate a familial relationship between Heidelberg man, Neanderthal man, Boskop man and the South African Australoids.

Concluding Remarks

This investigation has shown that a number of teeth discovered at Zitzikama exhibited the condition of taurodontism and that taurodontism is also of frequent occurrence in the teeth of living South African races. In none of the dentitions examined, however, was the condition of taurodontism as well marked as in the teeth of the Krapina or Jersey Neanderthaloids, even although in many instances the teeth examined exhibited the character relatively as clearly as the teeth of the Heidelberg jaw.

It was found that although the Bantu and Bush peoples possessed teeth of the cynodont type, taurodont teeth occur in South African hybrids where the elements of fusion are Australoid or Boskopoid with cynodont types. From this it was concluded that taurodontism is a character of South African Australoid and Boskopoid peoples.

The fact that taurodont races have intermingled with cynodont races of mankind and produced fertile offspring is considered to show that taurodontism is not a character of zoological species rank. The frequency of occurrence of the condition in hybrids showed that taurodontism is probably a Mendelian recessive character and since, in the Mendelian sense, taurodontism was found to breed true, it was concluded that taurodontism must be a character of at least variety rank.

Finally, from a consideration of these facts and from the frequency of occurrence of the character and its wide geographical and historical distribution, it was concluded that until convergence was demonstrated it appeared preferable to regard taurodontism as a primitive character and the people possessing the character as having come from one stock.

In conclusion, I desire to thank Prof. Raymond A. Dart for numerous helpful suggestions and criticisms during the investigation. I also wish to acknowledge my indebtedness to Messrs Krynauw and Le Helloco, students of this University, and to my friend, Mr W. Tamson, for the drawings with which this paper is illustrated.

BIBLIOGRAPHY

Adloff, P. (1908). *Das Gebiss des Menschen und der Anthropomorphen.* Berlin.

—— (1910). "Neue Studien über das Gebiss der diluvialen und rezenten Menschenrassen." *Deutsche Monatschrift f. Zahnheilkunde,* xxviii, pp. 134–159.

Azoulay and Regnault (1893). "Des diverses formes des dents incisives supérieures." *Bull. de la Soc. d'Anthropol. de Paris,* xvi, pp. 266–269.

Boule, M. (1923). *Les hommes fossiles.* Deuxième édition. Masson et Cie, Editeurs, Boulevard Saint-Germain, Paris. Pp. 145–146.

Broom, R. (1925). "A contribution to the craniology of the yellow-skinned races of S. Africa." *Journ. Roy. Anthrop. Inst.* liii, pp. 132–149.

Campbell, T. D. (1925). *Dentition and palate of the Australian Aboriginal.* Publications under the Keith Sheridan Foundation, No. i. Adelaide. Pp. 18–19.

COURTNEY LYNE, W. (1916). "The significance of the radiographs of the Piltdown teeth." *Proc. Roy. Soc. Med., Odont. Sec.* IX, pp. 33–51.

DART, R. A. (1923). "Boskopoid remains from the South-East African coast." *Nature*, CXII, No. 2817, pp. 623–625.

GORGANOVIC-KRAMBERGER, K. (1907). "Die Kronen u. Wurzeln der Mahlzähne des Homo primigenius und ihre genetische Bedeutung." *Anatom. Anzeiger*, XXXI, Band, Nr. 4, u. 5, pp. 97–134.

GREGORY, W. K. (1920). "The origin and evolution of the human dentition." *Journ. Dental Research*, II, No. 4, pp. 696–697.

—— (1921). "The origin and evolution of the human dentition." *Journ. Dental Research*, III, No. 1, pp. 139–197.

HOPEWELL-SMITH, A. (1913). *An introduction to dental anatomy and physiology.* First edit. (J. and A. Churchill), London. Pp. 174–221.

—— (1919). *The normal and pathological histology of the mouth.* Second edit. II (J. and A. Churchill), London. Pp. 213–214.

HRDLIČKA, A. (1914). *The most ancient skeletal remains of man.* Report, Smithsonian Inst. No. 2300. Government Printing Office, Washington. Pp. 491–552.

—— (1920). "Shovel-shaped teeth." *Amer. Journ. Phys. Anthrop.* III, No. 4, pp. 429–459.

KEITH, A. (Sir) (1913). "Problems relating to the teeth of the earlier forms of prehistoric man." *Proc. Roy. Soc. Med. Odont. Sec.* VI, pp. 103–119.

—— (1916). *The antiquity of man.* Third edit. (Williams and Norgate), London. Pp. 147–148, 473–478.

LAING, G. D. (1924). "A preliminary report on some Strandlooper skulls from Zitzikama." *S. African Journ. Science*, XXI, pp. 537–539.

MILLER, G. S. (1915). "The jaw of the Piltdown man." *Smithsonian Misc. Col.* LXV, pp. 1–31.

MUMMERY, H. (1923). *The microscopic and general anatomy of the teeth.* Second edit. Oxford Univ. Press, pp. 369–421.

NEHRING, A. (1895). "Ueber einen menschlichen Molar aus dem Diluvium von Taubach bei Weimar." *Verhandl. Berliner anthropl. Gesellsch.* pp. 573–577.

SOLLAS, W. J. (1924). *Ancient hunters.* Third edit. (Macmillan and Co.), London. Pp. 235–236.

TOMES, C. S. (1923). *A manual of dental anatomy; human and comparative.* Edited by H. W. Marrett Tims and C. Bowdler Henry. Eighth edit. (J. and A. Churchill), London. Pp. 1–2, 520–527.

WILLIAMS, J. L. (1914). "A new classification of human tooth forms; with special reference to a new system of artificial teeth." *Dental Digest.* XX, pp. 63–67.

EXPLANATION OF PLATE I

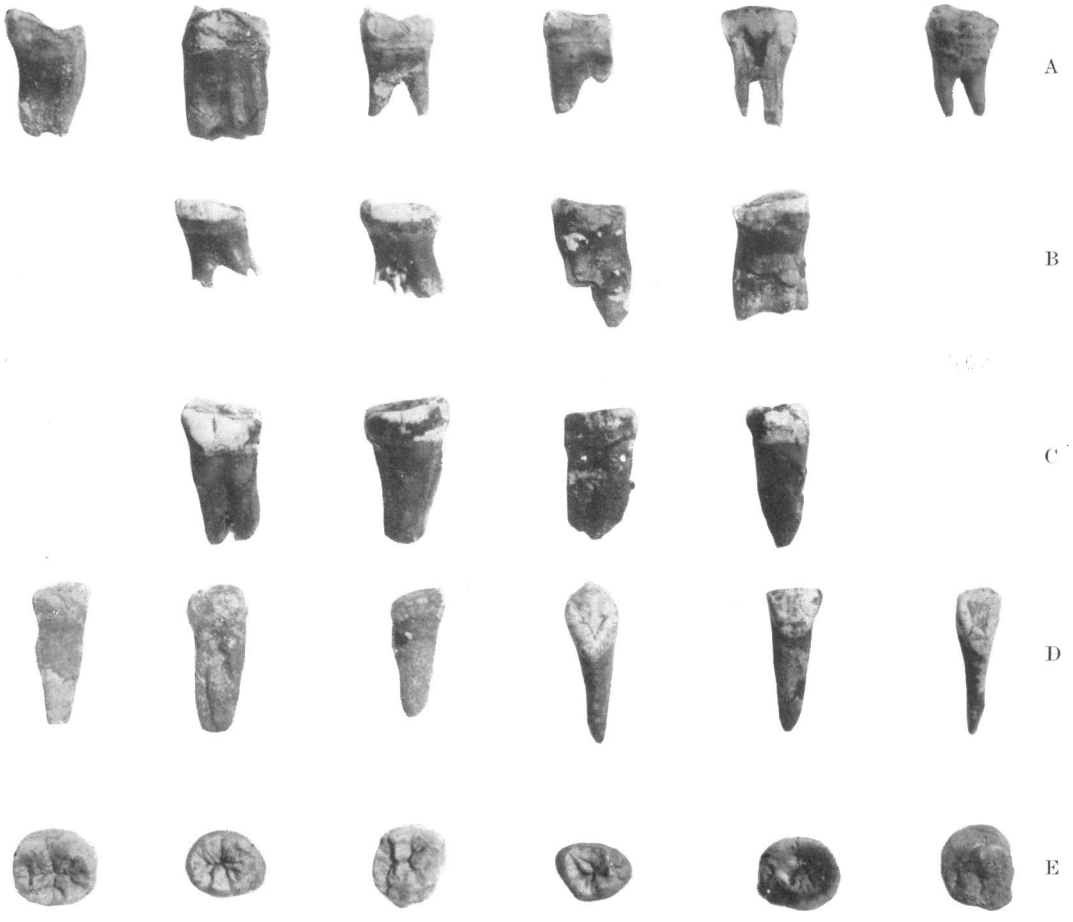
Row A. The Strandlooper molars (reading from left to right). Lower second molar, upper second molar, upper first molar, upper second molar, upper first molar, lower first molar. (From Zitzikama.)

Row B. The Boskop molars (reading from left to right). Lower second molar, lower first molar, upper second molar, upper first molar. (From Zitzikama.)

Row C. Bantu-Boskop hybrid's teeth (reading from left to right). Lower first molar, lower second molar, lower third molar, lower first premolar—all from the left side of one individual. (Skull 117.)

Row D. The Strandlooper anterior teeth (reading from left to right). Upper premolar, lower first premolar, upper premolar, upper canine, upper first incisor, upper second incisor. (From Zitzikama.)

Row E. The Strandlooper molar crowns (reading from left to right). Lower molar crown, lower molar crown, upper molar crown, upper third molar crown, lower molar crown, upper molar crown. (From Zitzikama.)


A
B
C
D
E