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SHARPNESS OF TEETH IN MAN
AND OTHER PRIMATES

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ABSTRACT

Analyses of wear characteristics on the teeth of a young adult male baboon, a male native human from New Guinea and a male Caucasian from New Zealand are made, and their insepa-rable relationship to behavior emphasized. These characteristics provide evidence of the evolution of precise anatomical and in-nate behavioral tooth-grinding mechanisms specific to the pro-duction of sharp teeth. Although the teeth on eruption have some degree of morphological sharpness, the tooth-grinding behavior perfects this sharpness and subsequently maintains it throughout the functional life of the teeth. The male baboon, used here as broadly representative of man's non-hominid relatives and an-cestors, has a specialized, sickle-like, vertically oriented upper canine, sharpened specifically as a slashing weapon. The lower anterior premolars are the honing tools which grind against the upper canines in a motion opposite to that of the masticatory stroke. These premolars are noticeably specialized for this tooth-to-tooth grinding action by their enlarged buccal crown-faces, thickened enamel gingival extensions, and by paired roots placed perpendicular to the "whetstone" faces.

In contrast, man's short-canine condition has evolved to pro-vide a specialized, horizontally sharp shearing device. The con-tinuous rows of even, constantly sharpened teeth, vertically oriented and firmly anchored in jaws which provide greater force at the biting teeth, give man the capacity for powerful, lethal,

"segmentive" biting. Thus man's dentition is seen not as "generalized", and certainly not as "regressed" or "weakened", but as highly specialized. The significance of the short-canine condition (currently regarded as a diagnostic feature of hominids) is not that man has become biologically defenseless, but that the hominid dental mechanism has harnessed attritional wear to provide a more stable and durably functional weapon.

It is concluded that tooth-sharpening and related phenomena are evidence of innate behavior related to a specialized, viable, biological weapon in *Homo sapiens*, and because this weapon — the teeth — is the primary one and has been overlooked it emphasizes a corollary: intraspecies use of the teeth is strictly controlled by genetical determinants, whereas such control of the secondary weapon — the hand — is slight.

Introduction

The prime evolutionary advantage of mammalian and especially primate teeth — their sharpness — has previously received little discussion in the literature. The special morphology of these teeth, and the fact that they are composed of enamel and dentine (the hardest and most durable of biological substances) gives them the capacity to penetrate and divide exogenous materials. Because the initial morphological sharpness of unworn teeth is so advantageous, mechanisms to perfect and maintain this sharpness through progressive wear are further advantageous and have evolved as important characteristics of mammals (with very few specialized exceptions, e.g., the toothless anteater and baleen whale).

The fossil record suggests that in the evolution of the hominid dental system leading up to *Homo sapiens* there was a period of rapid transition in such mechanisms. Apparently with a few million years, at the most, there was a switch from the pongid condition of vertically sharp upper canines to the condition seen in recent hominids of horizontally sharp teeth. As continuous rows of short, even teeth assumed the role of weapons, the weapon-like action of the dentition changed from slash to bite. Moreover, the process of precise attrition-sharpening, (*thegosis,* see below) was extended to include all upper and lower incisors and canines. This was a considerable addition to the premolar-plus-molar, horizontal shearing blades which emerging hominids already possessed. Incision, furthermore, was profoundly improved by the significant addition of a unique feature — antero-posterior (retrusive) shearing; it was no longer a simple vertical (orthal) action in the canine-incisor region, such as that seen in the non-hominid anthropoids today.

In previous reports that introduced my tooth-sharpening hypothesis (Every, 1960, 1965), figures were not presented. In the present paper, figures are included and the major arguments of the hypothesis are discussed; special attention is given to considerations of dynamic spatial relationships among dental structures. Furthermore, it is emphasized that these anatomical considerations can be understood only in the light of corresponding ethological considerations, of which they are an integral part. Tooth-sharpening and related phenomena give a new

dimension to the study of mammals (particularly). Out of the immense amount of detail already emerging, this paper concentrates on that related to *Homo sapiens,* his hominid ancestors and anthropoid relatives.

Functional Anatomical Considerations

NON-HOMINID ANTHROPOIDEA

The baboon (*Papio*) shows an extreme specialization for vertical sharpness of the canine and is therefore chosen to illustrate functional anatomical adaptations in cercopithecoids (Figs. 1-3).

Important features of the baboon upper canine are as follows (Fig. 1):

1. Facet striated by wear from *attrition*[1] (the discrete wear from the forceful grinding of the surface of one tooth against that of its opposite, i.e., tooth-to-tooth contact wear). See also Figure 4 and discussion.

2. The absence of wear from *abrasion* (the diffuse wear from friction of exogenous material). Compare with Figure 4.

3. The thin enamel coating on the palatal surface (indistinctly shown on the mesial side of the facet, and on the less extensively worn gingival third of the crown).

4. The relatively thick enamel coating on the labial surface (indistinctly shown by the strip of enamel which forms the distal edge — the cutting edge — of the crown).

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[1] The basic material of this paper was first prepared as the legend and discussion of five illustrations (here figured 1-5) and submitted for publication in 1964 along with the article "The teeth as weapons; their influence on behaviour" (Every, 1965). At that time I used "attrition" and "abrasion", terms I had differentiated and given specific meaning (Every, 1960). Hitherto in the literature these terms were used synonymously. Since then, however, I have used a new term, *thegosis* (from the Greek, *thego,* to whet, sharpen). My argument for the use of *thegosis* as more appropriate to an evolutionary adaptive phenomenon, and taking precedence over *bruxism* (a term poisoned by a current definition of mal-adaption, pathology and myth) is developed in another paper, in preparation. Since numbers of scientists are already familiar with my term *thegosis* I shall, therefore, use it in the remainder of this paper.

5. The concavity of the vertical cutting (distal) edge; it tends to a sickle-like formation. The distal edge is also concave when viewed directly from behind. This is because the palatal surface itself is distinctly concave, and this extends the length of the crown. The reflected light in this unretouched photograph, therefore, comes from the apical part of the facet only.

6. The continuity of the concavity of the thegosis-facet. This extends vertically from the gingival border of the facet to the apex of the crown. There is no rounding-over (convexity) at the apex. The tooth is thus ground to a sharp spike.

7. The continuity of the thegosis-facet in the mesiodistal (horizontal) aspect. There is no rounding-over at the distal edge of the crown, the blade of which is thus ground to a fine edge.

An examination of the origin of the attrition-facet of the upper canine reveals specializations characteristic of non-hominid catarrhines; these facets are adapted for producing and maintaining sharpness of the weapon. The grinder (the cutting tool, the hone or whetstone) is the lower anterior premolar, P_3 (Fig. 3). Its morphological and structural characteristics make it possible to identify this tooth as a specialized sharpening tool. Moreover, this is its major function. It is not in any way specialized for shearing or sectioning, as is widely believed. The buccal surface of the crown of P_3 is an elongated area of thick enamel which is continuous from apex to gingival extension and which forms a hard grinding surface relatively unyielding to wear. In all other teeth of *Papio* (except the lower canine at its tubercle — see below) there is a gradual thinning of enamel towards the gingival edge. Thin enamel extends over the whole of the palatal surface of the upper canine, a feature which allows it to yield easily to grinding against P_3, and the underlying dentine, when exposed, yields even more readily.

Specialization of this sharpening tool is further evidenced by its roots: it has two; the distolingual is heavier than the mesiobuccal, and the line in which they are placed is at right angles to the crown's grinding surface. Such precise arrangements are clearly to withstand the force of the laterally directed sharpening action.

Lower anterior premolar root formations, concomitants of the

FIG. 1. Palatal surface of upper right canine tooth: young adult male baboon. This view is inverted so that the direction of its cutting (distal) edge faces in the same direction (left) as in Figs. 2 and 3.

STRIATIONS IN DENTINE
CUT (GROUND) BY THE
BUCCAL ENAMEL OF
LOWER ANTERIOR
PREMOLAR

EDGE OF
THICK LABIAL
ENAMEL:
THE SHARP
CUTTING EDGE

ENAMEL

DENTINE

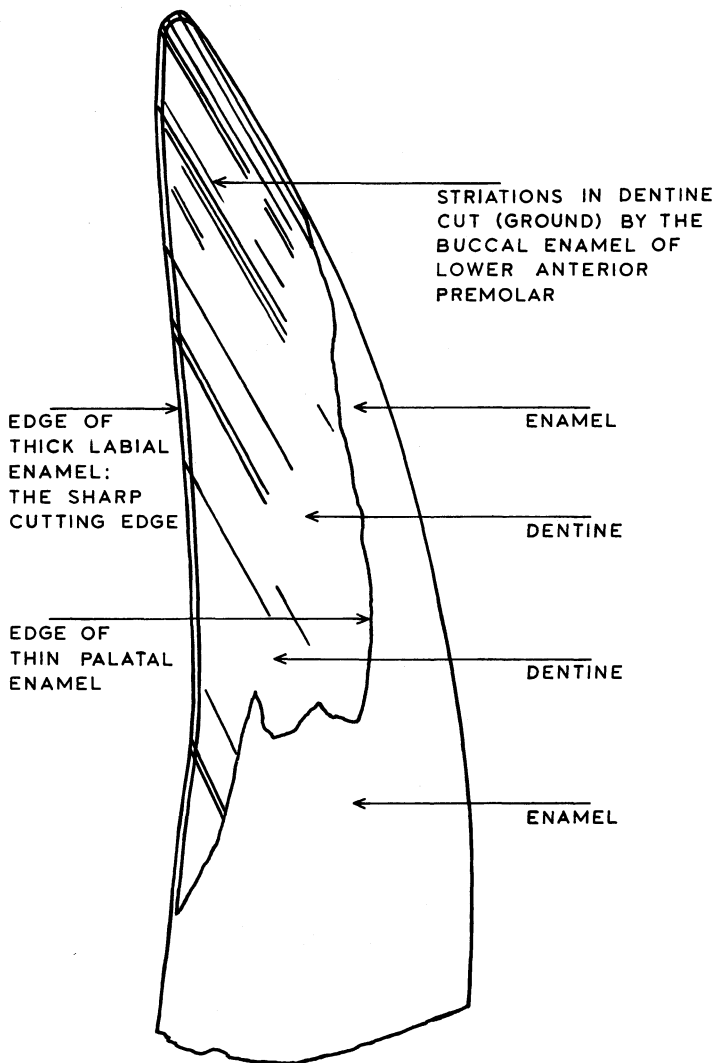EDGE OF
THIN PALATAL
ENAMEL

DENTINE

ENAMEL

FIG. 1. (cont.)

vertically bladed upper canines, reappear with significant fre-
quency in *Homo sapiens* (Tomes, 1923), strongly to suggest an
origin from long canined ancestors. Earlier hominids, the
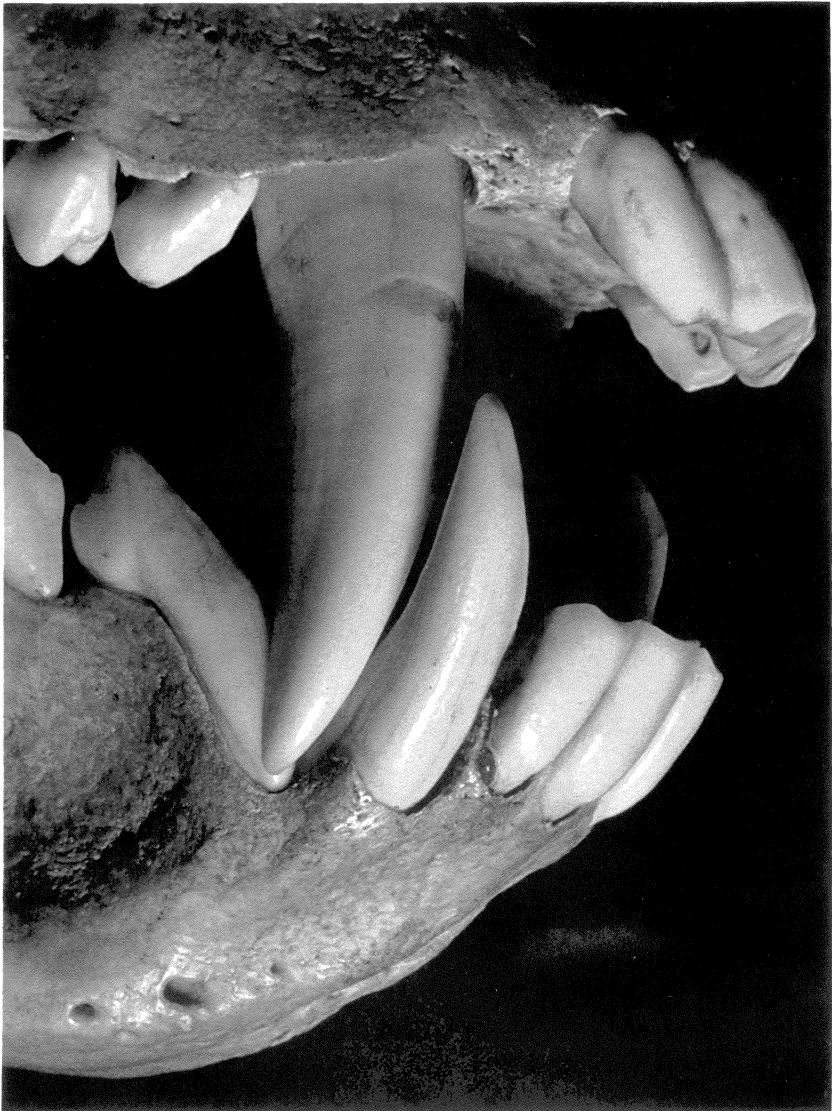*Australopithecus*, show this even more distinctly, as they do the

FIG. 2. Terminal phase of premolar grinding the canine in young adult male baboon.

ABRASION ROUNDED
INCISAL EDGE
(RIGHT CENTRAL INCISOR)

CANINE

ANTERIOR
PREMOLAR

DENTINE

ENAMEL
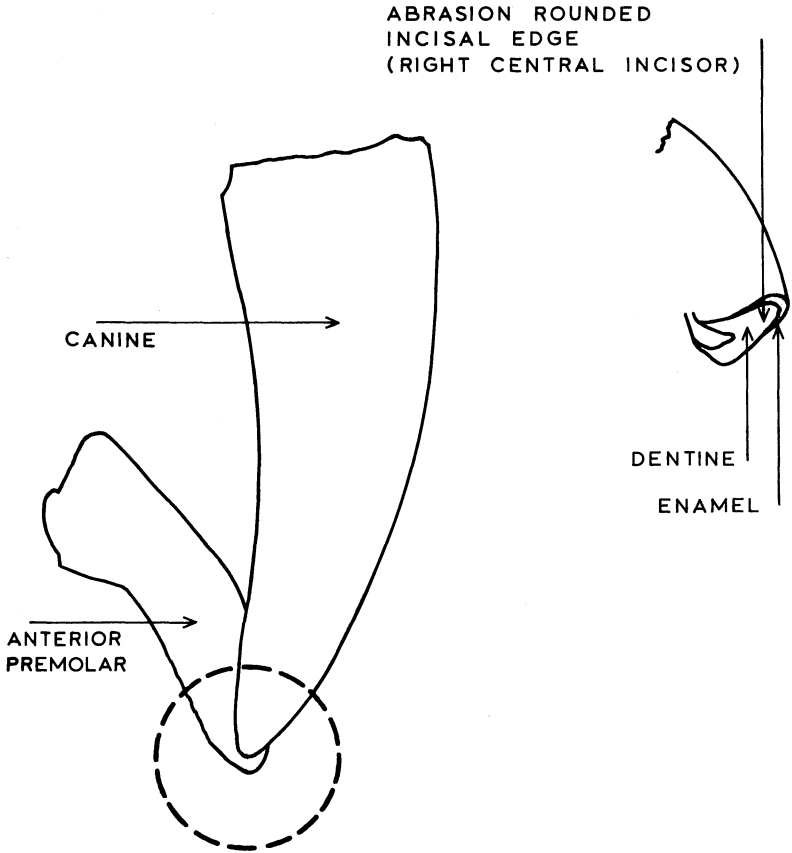
FIG. 2. (cont.)

feature of a distogingival tubercle on the lower canine. The report of these (overt) features (Robinson, 1956) does not, however, relate their concomitance (see below).

Contrary to current understanding, the motion of the mandible in this tooth-to-tooth wearing action is not as it is in mastication. The masticatory stroke, in the terminal phase of the masticatory cycle, is an approximation of the teeth, in a medial, i.e., buccal to lingual (ectal) movement; it terminates in central position. In contrast, the sharpening movement starts with the teeth in central

FIG. 3. Beginning phase of canine grinding canine in young male adult baboon.

ANTERIOR PREMOLAR

FACET ON
DISTAL SURFACE
OF LATERAL
INCISOR

ANTERIOR PREMOLAR

CANINE

CANINE

THICK
ENAMEL

THIN ENAMEL

TUBERCLE:
THICK ENAMEL

GINGIVAL EXTENSION OF CROWN: THICK ENAMEL
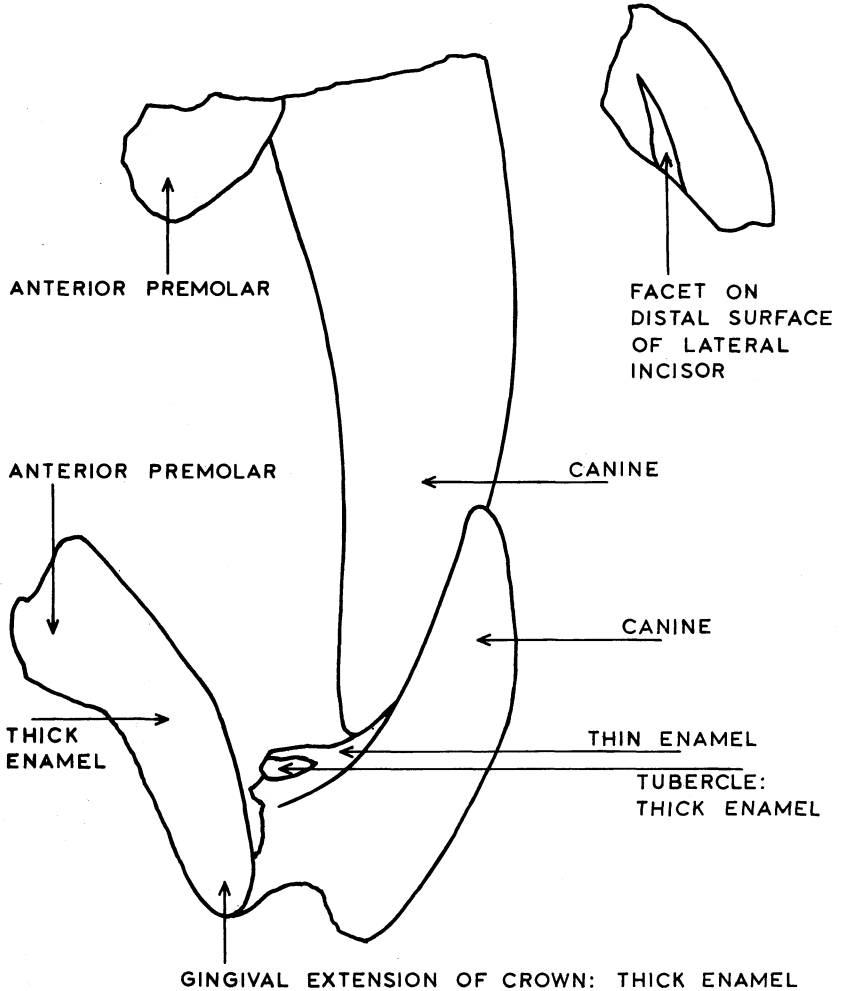
FIG. 3. (cont.)

occlusion. The mandible is extended laterally, i.e., from lingual to buccal (ental) movement, and is concurrently depressed. This is effected by action of the external pterygoid muscle on one side alone, in combination with the depressor muscles (chiefly the digastric) of the mandible (Every, 1965). The strokes are rapid, and the sound produced by such grinding in many animals has frequently been heard but has been recorded merely as tooth-chattering (e.g., van Hooff, 1962); it has, moreover, been inter-

preted solely as an action deriving from tension and perhaps as a signal — nothing more.

The audibility of tooth-grinding (chattering) and the lack of any such sound in masticatory tooth-to-tooth contact is consistent with the proposition that man's teeth seldom, if ever, meet in masticatory or incisive action; they meet when swallowing, but even then too lightly to produce significant wear (Jankelson, Hoffman, and Hendron, 1953; Yurkstas and Emerson, 1954; Anderson, 1955). Attrition (thegosis) does not occur during chewing and swallowing because masticatory and incisive strokes are terminated, presumably by proprioceptive reflex, just short of contact between opposing teeth. The division of exogenous material is achieved as the teeth approximate; should the teeth make contact no further advantage would be achieved, and the production of uncontrolled wear would be a serious disadvantage.

The presence of the tubercle situated distogingivally on the baboon lower canine tooth (Fig. 3) provides a further example of morphological, structural, and behavioral specialization which has evolved as a result of the advantages of the sharpening process. The previously unexplained function of the tubercle can now be understood as a specialization to protect the apex of the upper canine in the terminal phase of the grinding stroke. Fig. 2 depicts this position. At the critical phase, where the apex of the canine is poised precariously on the gingival extension of the premolar crown, the hazard of maintaining the necessary grinding pressure without rounding over, and thus blunting the apex, is eliminated by the presence of the tubercle. This tubercle contacts the upper canine tooth higher (gingivally) on its crown, an arrangement which (with further mandibular action) allows the apex to disconnect from the grinder without change of direction and thus without damage. The tubercle supports the lateral pressure at the termination of the grinding stroke, and as a result, possesses a thicker coat of enamel than the remainder of the lower canine crown in this area.

Further sharpening of baboon canine apices is effected by grinding the lower canine apex against the apex of the upper. The beginning of this action (shown in Fig. 3) appears to require a shift from lateral (extrusive) action of the mandible to retrusive action but with the mandible still held in a lateral position. It is possible, however, that no change of action is necessary and

that the two can occur independently. Retrusion is limited by the postglenoid tubercle of the temporomandibular joint. There is, nonetheless, sufficient freedom in the baboon's temporomandibular joint (only slight movement is necessary) to allow some forceful contact with the distal surface of the upper canine, and thus effect a mutual sharpening of each apex[2].

The apex of the lower canine is further sharpened by yet another action of the mandible which grinds it against the distal surface (shown in Fig. 3) of the upper lateral incisor. This action, which affects the mesiolingual surface of the lower canine, is concurrent with the beginning of the major weapon-sharpening action on the opposite (contralateral) side of the mouth.

In the baboon, as in many non-hominid Anthropoidea, the enamel of the upper canine's anterior surface is grooved to form two vertical columns. The corresponding (anterior) and the opposing (distal) surfaces of the lower canine are not grooved; moreover, both the ground (distal and lingual) surfaces have only a thin coat of enamel. This arrangement favors sharpening of the lower canine apex, yet maintains the continuity of buccal and mesial enamel on the upper canine. This is vital to its piercing and cutting efficiency. Although the apices of both canines are sharpened, it is the upper canine, with its acute blade sharpness, (entirely absent in the lower canine), which is the dominant weapon. The action of the upper canine in the baboon (reflected in the strong nuchal musculature; Every, 1965) is in slashing in a downward, backward, and inward direction. Even when biting, this distally sharpened blade, shaped as a sickle (see No. 5 above) and oriented posteriorly, remains exposed; it is the crown's mesial surface which is covered by the overlapping lower canine. The upper canine serves as an efficient weapon rather than as a grasping organ[3].

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[2] The postglenoid tubercle is, significantly, absent in many mammals, particularly the rodents and lagomorphs. Its absence in the pig is part of this animal's specialized temporomandibular joint which permits retrolateral mandibular action — an adaptation for sharpening the lower canine tusk.

[3] This is in marked contrast to the typical carnivore condition where canines, aided by a large diastema, double in function as weapons and grasping tools, and although their rounded distal surfaces may show vertical ridges, these are slight and do not impair the vital — for a carnivore — grasping advantage of the relatively blunt, hook-shaped walls.

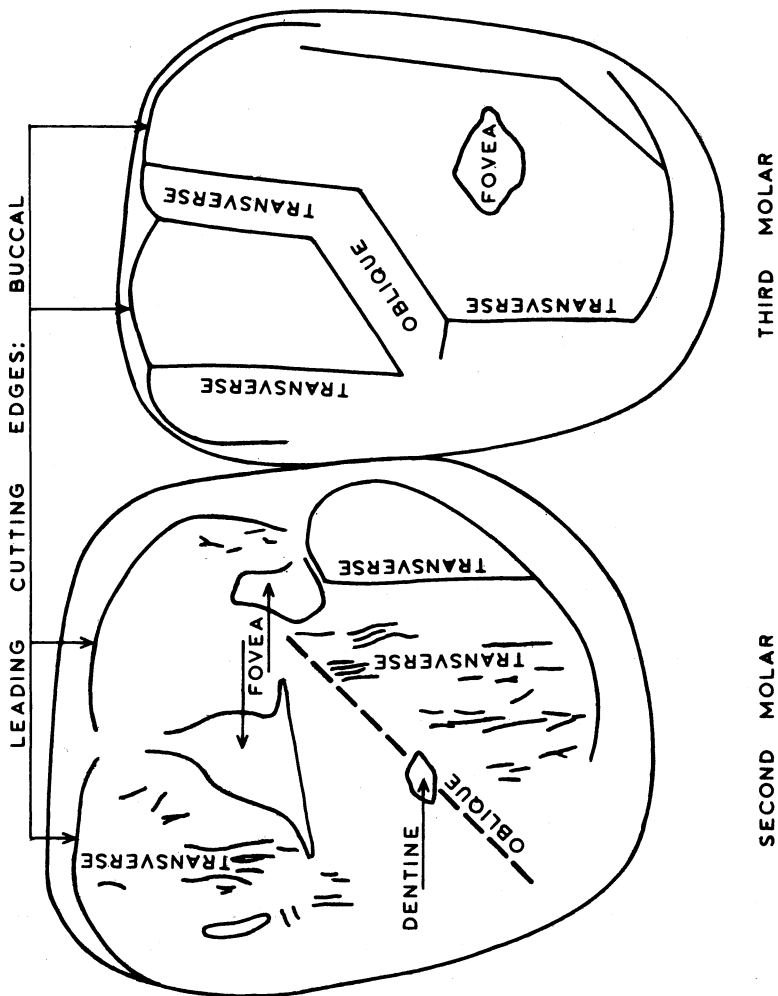FIG. 4. Upper left molars of a male human native of New Guinea.

FIG. 4. (cont.)

HOMINIDS

Figure 4 shows some of the features of wear and sharpening
processes in the molars of *Homo sapiens*. The third molar, with
six to eight years' less use than the second molar, shows a clear
picture of wear principally from the tooth-to-tooth contact wear

of thegosis. This wear is the result of two discrete mandibular movements which have produced two equally discrete sets of facets (some of these are high-lighted in the photographs); the facets form ridges and grooves which meet at distinct boundaries. The transverse boundaries (vertical in the photograph) are formed by a left lateral (extrusive) thegosis action. In this action the mandible rotates about an axis at the left postglenoid tubercle (see discussion of Fig. 5, below), i.e., about a point posterior to the mandibular condyle on the same (ipsilateral) side as the teeth in the figure. This movement is in exact opposition to that of the masticatory stroke in its terminal phase, and therefore must occur apart from mastication. The oblique boundaries are formed by a lateral mandibular movement, i.e., the mandible rotates about an axis at the postglenoid tubercle on the opposite (contralateral) side. As this movement is beyond the terminal phase of a masticatory stroke, the oblique facets are also fashioned apart from mastication.

Wear from abrasion (in this instance, the friction of food) is predominant in the second molar because it has had from six to eight years' more use than the third molar; there is, however, a small thegosis-facet on the remnant of the distal surface of the distopalatal cusp (hypocone). Mesial to this distal thegosis-facet, with its discrete transverse ridge, are irregular, but still transversely oriented, lines. These are the result of friction scouring by exogenous material. In contrast to the thegosis-facet, the more heavily abraded remainder of the occlusal surface of this second molar has no precise occlusal conformity with an antagonist.

Three other key features are to be seen on this second molar:

a) The prominent sharp edge to the buccal cusps, from which the chewing table slopes down to the less prominent palatal cusps (the incline is more apparent in a mesial or distal view). This buccal edge is (relative to the movement of the lower molars) the leading (cutting) edge of the upper molar; it forms a crest on the tooth's vertical, relatively flat, buccal surface. In the lower molars the corresponding leading edge and vertical, relatively flat, surface is lingual.

b) The worn concavity of the palatal aspect of the buccal cusps. This feature, which helps to maintain the sharpness of the leading edge, is formed as a result of specializations in the temporo-

mandibular joint, in the mandibular symphysis, and in the proportions of the basal skull, maxillae, and mandible.

c) The remnant of the oblique ridge connecting the distobuccal cusp with the mesiopalatal cusp. Midway along the palatal section of this ridge is a small area of exposed dentine. With progressive wear from the friction of masticatory action other areas of dentine are exposed and gradually increase in size, and because dentine is a softer substance these areas become hollowed out. This phenomenon is characteristic of most mammals and provides a most important adaptive feature in allowing additional enamel cutting edges to appear (i.e., around the boundaries of the abraded dentine), thus maintaining — even enhancing — the sharpness of the tooth throughout its life.

Figure 5 shows some of the features of wear and sharpening processes on the incisors and canines of *Homo sapiens*. The principle reason for inclusion of this figure is to demonstrate the incorrectness of the hypothesis that states that excessive tooth wear in civilized man is the result of a "heavy bite". This hypothesis also often includes the proposition that heavy wear may have atavistic components, occurring more frequently in culturally primitive races (the traditional example given is the Australian aborigine).

Heavy wear is most often accounted for (e.g., Zuckerman, 1958) by assuming that use (age) wears hominid teeth down from their tips, and that they become flat and blunt as a result. Fig. 5, however, clearly shows a picture of wear which is dominated by thegosis, with the remaining loss of tooth substance resulting from decay, abrasion, and erosion. There is also evidence that thegosis occurs on distinctly separate occasions from incision and mastication, i.e., in the absence of exogenous material. Furthermore, it is possible to determine that the mandibular stroke producing thegosis is both oblique to the incisive stroke, and extrusive. Its action is in contrast to that of the terminal phase of incision, which is directly retrusive. This is shown by:

1) The thegosis ridges on the right (left side of the picture) canine, and (indistinctly) on the right central incisor. These thegosis ridges form arcs which are concentric with the transverse ridges on molars situated on the same side (ipsilateral),
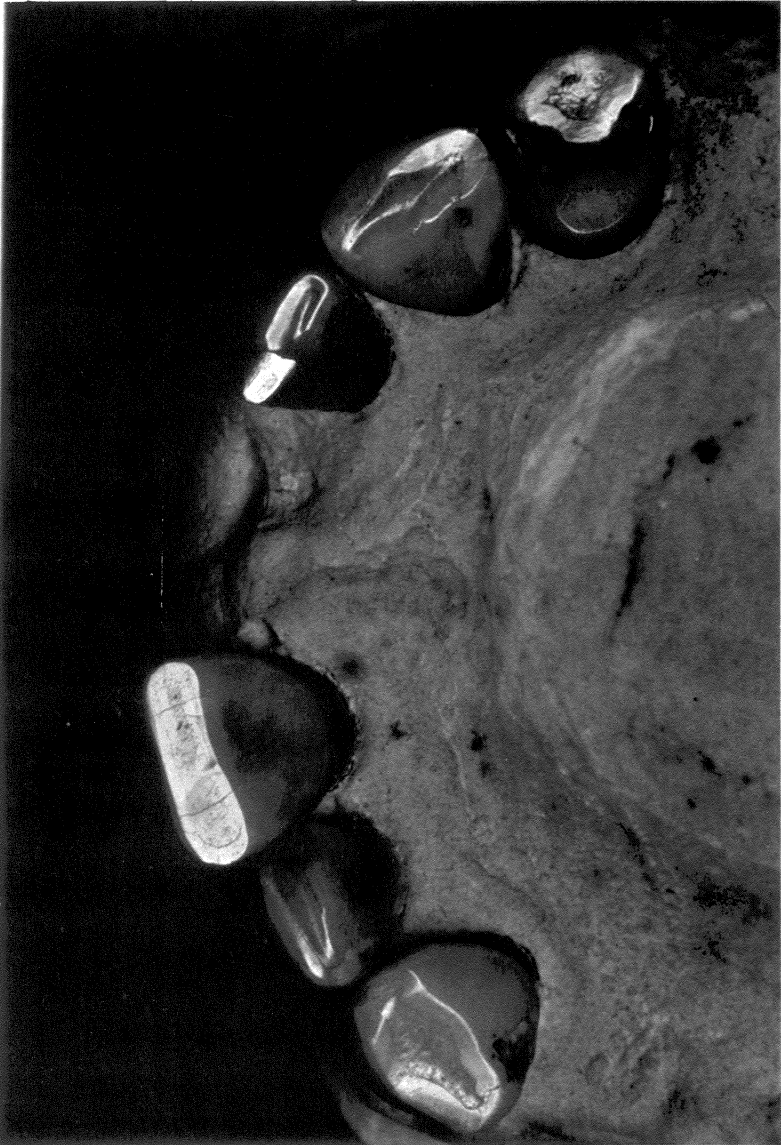
FIG. 5. Three remaining incisors, two canines, and one premolar from the upper jaw of a Caucasian male New Zealander.
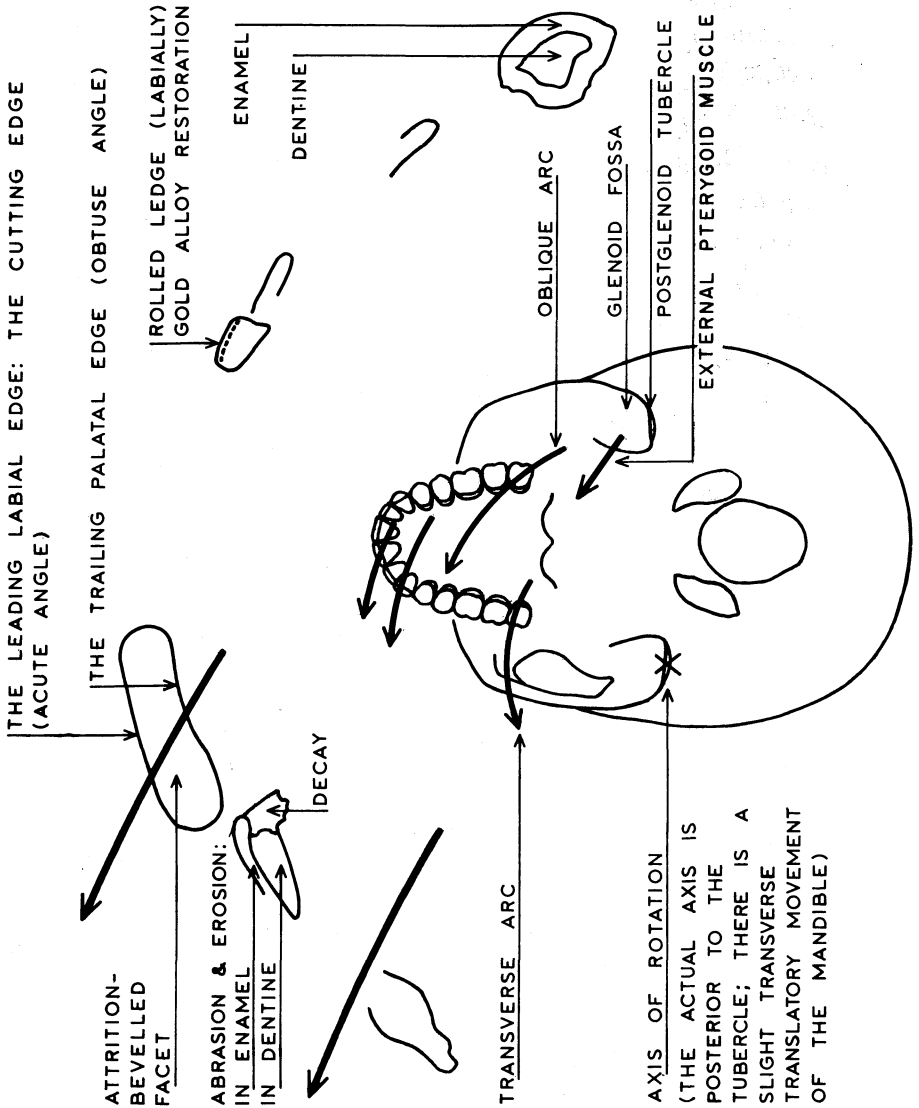
FIG. 5. (cont.)

and with the oblique ridges on the opposite (contralateral) side of the dental arch.

2) The gold-alloy restoration of the mesial incisal angle of the left lateral incisor which has the appearance of being repeatedly

beaten. The wear on all the anterior teeth shows that their occlusal relations to the lower anterior teeth are now relatively edge-to-edge; there is evidence of an overjet but no overbite. If the current notion were true — that normal wear on anterior teeth is a result of incision — this action would be expected to produce a palatal rolling over of the malleable alloy, since the terminal phase of incision is a retrusive mandibular stroke (particularly in this edge-to-edge specimen where there is no overbite). But the alloy is rolled to a labially projecting ledge. It has been hammered over to produce a ledge, as in a rivet. This can only have occurred under an action of forceful occlusion — an action distinct from and incompatible with incision or mastication (Every, 1965).

3) The flat incisal facet on the right central incisor. Especially when there is a normal incisor overbite and overjet relationship, this characteristic flat formation can be caused only by a mandibular movement which extensively crosses over the two rows (upper and lower) of anterior teeth. That is, the row of lower anterior teeth must cross over, and become diagonally related to, the row of upper anterior teeth. This is actually achieved by extensions of the same movement which grinds facets on the molars. (See evidence outlined in discussion of Fig. 4.)

4) The angle that a typical upper incisal facet makes with the vertical labial surface is about 76°. (Although this is not apparent in the figure, the incisal facet is inclined palatally). The fallacy that these teeth wear blunt is exposed by noting that the flat facet is the bevel to the sharp, leading, labial edge. In the lower teeth, the sharp, leading, cutting edge is the lingual boundary of the incisal facet. In contrast to man, the baboon's incisors (see Figs. 2 and 3) are more likely to wear blunt; but this is an abrasive bluntness: the baboon cannot grind bevelled facets on its incisal edge — any possible crossing over of occluding upper and lower rows of anterior teeth is prevented by the baboon's long canines and jaw proportions. Furthermore, relative to the pongid condition and, by inference, that of the hominid's long-canine-toothed ancestors, the lingual enamel which forms the sharp cutting edge of lower incisors and canines is thickened. Although the corresponding sharp edges of upper incisors and canines are labial, the palatal enamel of these teeth is also thickened. This, however, is to the advantage of the stage of wear when dentine

becomes exposed and hollowed out by abrasive wear (see discussion of Fig. 4). When this occurs the thickened palatal enamel provides an additional cutting edge, and is also subject to thegosis. This feature, of course, correspondingly occurs, but in the reverse relationship, in the lower teeth; the new cutting edge, which appears when dentine is exposed, forms a crest on the labial enamel[4].

Discussion

When man fabricated his first stone chisels, he found an optimum angle of bevel which was advantageous in cutting and durability. He had probably learned much from his use of other animals' teeth as chisels. In his use of either stone or teeth he would not have directly applied the flat bevel in the cutting stroke. Yet this inefficient action is imagined by some to occur in the functioning of man's own teeth; the flat facet on incisors of *Homo sapiens* is called the "incisal edge", whereas the real incisal edge is the boundary of the facet (the *edge* of the bevel), not its flat surface.

Hundreds of millions of years before man fabricated a functioning blade — a blade which, when blunted by use, was resharpened — natural selection had achieved numerous specializations for the maintenance and function of sharp teeth. It is a commonplace that, failure to discern a specific function for an anatomical feature does not imply that it is truly functionless. The "functionless" lateral incisors of the lagomorphs, for example, actually serve as specialized sharpeners; this is their dominant, if not exclusive, function (Every, 1967). By a stroke of the mandible at right angles to the incisive stroke an extremely fine "razor-edge" to the lower central incisor is honed[5]. The precision of this action in lagomorphs becomes even more apparent when it is seen that

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[4] This system of consecutive blades oriented relatively in a horizontal plane is seen more specifically in the selenodont molars of herbivores. Selenodont teeth only come into full function when dentine is exposed and hollowed out and the precise shearing blades (not rough, grinding surfaces) are brought into accurate alignment by thegosis — a genetically programmed behavior as in most other mammals. A characteristic selenodont molar then presents pairs of four consecutive, sickle-like blades, and each of the eight blades is precisely oriented to face the direct line of the masticatory stroke.

[5] The leading edge of the lower central incisor of lagomorphs and rodents in particular, and of most mammals in general, is labial.

the striations of the remainder of the extensive bevel are cut by the twin gouges which crest the incisal edge of the labial surface of the upper central incisor. This action involves a forceful protrusive mandibular stroke. Thus the two sets of striations on each bevel of the lower incisors are at right angles to each other and cannot have been caused either by grasping or by cutting of exogenous material. In marked contrast to this wear on the lower incisors is the characteristic wear from abrasion on the upper incisors, which likewise contributes to sharpening. (A detailed analysis of this will be presentèd in a later paper.)

The significance of all this to man is that it clarifies not only human dental morphology but also his innate tooth-sharpening behavior. It is important to emphasize that, for an animal to kill, two basic components must exist: a) the anatomical weapon, and b) the physiological mechanisms to activate it. These two components, though separate conceptually, are in functional terms inseparable. Aggressive behavior is unlikely to evolve, i.e., become genetically programmed, when there is no biological weapon. Learned improvements in aggressive behavior, moreover, are still less likely to occur in such a case.

In this light the hypothesis that the earliest hominid was biologically defenseless, and that improvements in the brain and hand produced aggressive behavior and cultural weapons "in compensation", is unconvincing.

The important part played by teeth in the evolution of most mammals is generally recognized, and particularly in the evolution of the hominids the teeth are considered to have played a vital part. But, paradoxically, this part is considered to be a negative one — the weapon is thought to have disappeared. In the light of the phenomenon of thegosis, however, these erroneous notions can now be discounted. The clarification of man's evolution concerns not only the evolution of his biologically inheritable features but also the evolution of his culture, which he does not inherit but acquires.

These subsequently learned cultural improvements in killing, however, today so occupy our attention that we tend to be oblivious of any unlearned components which may be programming our behavior. Any suggestion that innate aggression is a component of, human behavior we tend to regard as objectionable, as "animal" and "inhuman". And, at best, when its existence is recog-

nized, we hopefully believe that we may effect its control by avoidance, redirection, and sublimation.

It seems that the phenomenal success of our (learned) cultural achievements has caused us to fail to perceive the importance of precultural improvements in learning as facilitating genetical programming of behaviors. The increased capacity to learn is, of course, a biological improvement. The cultural improvement (particularly the overwhelming advantage of the accumulation of experience through the capacity to speak) is merely an extension of the same advantage. It is as if learning were the leaven to the dough: leaven does not constitute the food; it merely improves the food and enhances its ultimate utilization.

Interpretations of these hitherto unsuspected phenomena require reappraisals of both the palaeontological and the recent record of reptilian and mammalian life. In the case of man, the reappraisal includes not only aspects of his morphological characteristics, of his behavior and social organization (of those aspects which are genetically determined), but also of his culture — the feature which distinguishes him from other animals.

Furthermore, these interpretations are antithetical to many current ideas of the selective forces which produced man. They suggest, not merely a modification, but a reversal of ideas, particularly related to man's aggression. Certain notions, such as those aptly stated by Washburn (1960), become untenable: "The skull of the man-ape has transferred to its hands the functions of seizing and pulling, and this has been attended by a reduction of its incisors. Small canines and incisors are biological symbols of a changed way of life; their primitive functions are replaced by hand and tool."

Such misinterpretations of the relative grasping capacities of the dentition of higher primates can be disproved in the light of phenomena already well documented. For example: the assumption that there had been a transfer, in the "man-ape", of functions of seizing and pulling (to hands from teeth), suggests that no such transfer had occurred in the ape itself; yet I have seen no report of anyone having observed an ape transporting its young by its teeth, let alone supporting its own weight by grasping with its teeth; nor any report of any ape seizing and grasping an adversary, or a struggling prey, by its teeth. In contrast, the seizing and pulling capacity of man is demonstrated by his capacity to

seize and hold an adversary by his teeth, and by the circus per-
former's act where the force from the combined weights of two
individuals, plus the centrifugal force from their swinging as a
pendulum, is supported by the strength of one dentition.

Such a capacity is made possible in man by the improved
leverage of his jaws as a result of the shortening of the snout. It
is a feature which has allowed the reduction in the size of the
"masticatory" muscles without loss of force available at the
teeth (Every, 1965).

The grasping capacity of the sub-human primate dentition is
impaired, furthermore, by the acute sharpness of the distal edges
of the upper canine teeth. These canines do not double in func-
tion as grasping tools as do the carnivore's; they are specialized
as slashing weapons, and are more formidable than the carni-
vore's, which are poorly adapted for slashing. The grasping
function of a carnivore's canine teeth, however, is enhanced by
the bluntness of the walls of their crowns and by diastemata
posterior to, and thus exposing, their bluntness. Although the
slashing advantage is to the detriment of grasping, this is of little
consequence to a primate; the arboreal ancestors of all primates
show no evidence of their teeth having had dominant grasping
functions.

Washburn's statement quoted above that the transference of
functions had been "attended by a reduction of [the man-ape's]
incisors" suggests that there is a correlation between these factors,
i.e., large incisors are advantageous for seizing and pulling. Yet
the dentitions of characteristic carnivores, specialized for seizing
and pulling, have minute incisors, relatively a fraction of the
size of those of any anthropoid, including man.

Until the tooth-sharpening hypothesis first appeared (Every,
1960), there was, apparently, no suggestion that the hominid's
short canine teeth gave direct evolutionary advantage *per se*
to their possessor. On the contrary, evolutionary theorists widely
and confidently held that the canines had "regressed" and had
become "weak and inefficient". Moreover, they believed that, in
use, the canines "wore down from their tips" and soon become
"flat and blunt" — as did the hominid incisors, premolars, and
molars (e.g., Zuckerman, 1958; Leakey, 1960; Le Gros Clark,
1962). This was taken as evidence that biological progress in
early hominids had occurred in other features, particularly in the

brain and in the use of the hand, and that these morphological and cortical adaptations were "necessary" to offset the disadvantages of short, small, and weak teeth. This theory suggests that *Ramapithecus*, and certainly the earliest *Australopithecus*, must have had sufficient intelligence to use tools, if not to make them. It also suggests that this capacity must have been developed sufficiently to compensate for the absence of dental weapons during millions of years of what must on this theory have been extremely precarious existence. It is clear, however, that during the Pleistocene there was no lack of sizable predators. Early hominids were not fast runners; they had, as a result of bipedalism, a reduced climbing capacity, a low procreative rate, a reduced sense of smell and hearing, probably a lengthening period and increasing intensity of infant dependence, a small brain, no capacity to transmit accumulated experience by speech, and a comparatively limited capacity to transmit any experience by signals. In addition, evolutionary theorists widely held that the teeth were inefficient, not only as weapons, but also as tools of mastication, incision, and grasping. Despite all these disadvantages and hazards, early hominids were not overwhelmed; they managed to survive the long and critical epoch unprotected by the intelligence which is concomitant with a capacity for true speech, and supposedly unprotected by an effective biological weapon. This supposed achievement was made the more remarkable by the absence of one other significant and fundamental advantage which a biological weapon gave and still gives today. This advantage, moreover, is one which no artificial weapon presents or can ever present. It is that a biological weapon is built in; it cannot be dropped, mislaid, or lost, nor can its possessor be dispossessed, or taken by surprise "unarmed"; in an emergency it is always immediately available.

Conclusions

The evidence for the hypothesis of man's biological killing capacity can be studied in three aspects:

1. The anatomical weapon, i.e., the biological instrument of killing.

2. The permanent (inflexible) genetical determinants of killing behavior.

3. The transient (flexible) learned adjustments to the genetically programmed behavior.

The simple but fundamental hypotheses of tooth-sharpness and tooth-sharpening processes (thegosis) throw further light on the evolutionary events leading to man. The evidence suggests that in hominid evolution there was no period of defenselessness; the increased number of attrition-sharpened teeth, introducing the new and specialized feature of anterior shearing blades with a capacity for "segmentive biting"[6] (Every, 1965), was defensively, predatorily, and aggressively advantageous. It was especially advantageous when coupled with an increasing capacity to know and to signal when and where not to use the primary biological weapon.

The origin of the short canine by paedomorphic novelty is generally accepted (e.g., Koestler, 1966). Also accepted is the significance to evolutionary processes of paedomorphic novelty, which is not so much the initial event itself but that selection, here (operating on a more plastic, less committed stage) allows a sudden advance in a new direction. It is this sudden (now gerontomorphic) advance which, in the hominid short-canine condition, evolutionists have overlooked.

Once this process advanced to the stage where the relatively sudden appearance of a chin altered the shape of the oral cavity and the face, these prior advantages permitted the evolution of the further, and overwhelming, advantage of a capacity to speak (Every, 1965).

But along with this overwhelming advance in the capacity to learn came an inevitable disruption of the biologically balanced (unlearned) controls: the physiological reactions evoking and attenuating agonistic behavior. This disruption clearly resulted from two principal causes:

1. The introduction of the exogenous (artificial) weapon immediately gave lethality to the secondary, and fundamentally non-lethal, weapon — the hand. Being non-lethal (except by

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[6] I use this term (Every, 1965) to describe the separation and removal (in one action) of a large chunk of material.

accident) the hand is subject to relatively scant intraspecies (ritualized) control of its use, whereas the lethal primary weapon — the teeth — has its intraspecies use strictly controlled. That this control of agonistic behavior should be built in, i.e., automatic, stereotyped, species-specific (universal) and unlearned, is clearly advantageous. For, in agonistic behavior, especially when the weapon is sexually dimorphic (Every, 1965) in the adult, there is no margin of time allowance for learning: uncontrolled, random, trial-and-error actions of a built-in lethal instrument would rapidly lead to chaos. And if the species were to survive there would need to be strong selective pressure against learning the controls. This feature accounts for the restricted use of the primary weapon today, i.e., it is restricted in frequency of occurrence, force of bite, and selection of site; seldom are teeth used, seldom is a bite segmentive, and it is almost unknown for it to be sited at the fatally vulnerable neck.

2. The introduction of the exogenous weapon immediately extended the distance from the attacker in which the adversary could be injured. With sophistication of the weapon and progression of the distance this concomitantly and progressively dilutes the efficacy of the biological perceptions (seeing, hearing, touching, smelling, tasting) through which the controls are instrumented. Today, a kill can be made in circumstances devoid of direct biological perception. There is, as a result, almost complete disruption of the biologically balanced controls. The evoker, inevitably and tragically, is favored.

Genetical determinants of an animal's behavior can be considered permanent in the sense that they evolve in relation to permanent, or even relatively permanent, environmental features such as seasons, tides, bisexual reproduction, prey-food, and so on. Even less consistent but reasonably cyclic features such as droughts and famine can, in this sense, qualify as "permanent". When this permanency, i.e., inflexibility, is applied in the consideration of innate controls of killing behavior, whether it be predation, defense from predation, or intraspecies decimation in caged (e.g., overpopulation) circumstances, it is clear that especially for the higher animal, the capacity to learn is crucial. Because of the ever present non-permanent (i.e., transient) environmental circumstance, learning allows adjustment to the

timing and the movement of the innate sequence, and thus facilitates its consummation. In this view the capacity to learn is an inherent concomitant of the unlearned determinant of behavior — not a replacement.

Direct and comparative morphological studies of man's dentition, together with dental[7], psychological[8], psychosomatic[9], vertebrate paleontological[10], and paleoanthropological[11] studies of the conditions which evoke his sharpening behavior, suggest that man sharpens his teeth as weapons; he does not directly sharpen his teeth as tools of mastication or grasping. His teeth are adequately maintained as sharp tools in the normal frequency of their preparation as weapons.

The tooth-sharpening phenomenon uniquely presents a discrete entity of innate behavior in man which appears to be unclouded by argument that it could be learned. It, moreover, elucidates unlearned determinants of man's agonistic behavior, and strongly suggests that a partial measure of the (pre-cultural) biologically

[7] Experimental studies in loss (other than by caries and accident) of tooth substances; force and direction of mandibular action; i.e., using and devising techniques of conservative restoration, periodontia, therapeutic splinting and orthodontic appliance, full and partial prosthesis (allowing unique control of nocturnal action). (Every, 1939, 1949, 1960, 1965; Craddock and Johnston, 1961; Reed, 1968).

[8] Communication by facial expression, particularly (innate) signals and their auditory concomitants. Communication by olfaction. Relationship of (innate) unlearned and (cultural) learned determinants of behavior. Behavioral and morphological changes permitting the evolution of the capacity to speak. Pain thresholds in fight and flight. Use of tooth-sharpening as a marker of stress. (Every, 1960, 1965; Hughes, 1969).

[9] Oral symptoms of repression. Presentation of the *Syndrome of extreme mandibular movements*. Experimental therapy. (Every, 1946, 1960; Craddock and Johnston, 1961).

[10] The reptilian-mammalian transition. Mesozoic mammalian dentition, particularly in respect to the origin of the talonid and protocone, the contact point, the transition of cusp-interdigitation to cusp-apposition and opposing-convexities of shearing blades, and the significance to sharpness of differentially hard tooth-substances. Post-Mesozoic radiation. (Every, "Reinterpreting the dentitions of *Amphitherium* and *Peramus*," paper read at the Symposium of Vertebrate Palaeontology and Comparative Anatomy, London, 1967).

[11] The transition from vertically sharp slashing blades to horizontally sharp shearing blades. Evolutionary advantages of the hominid short-canine condition. Relationship of changes in the dentition to brain enlargement. (Every, 1965, and paper cited in Footnote 10).

balanced controls is restorable. But this only when man's (flexible) culture is made to harmonize with his (inflexible) biology.

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