age and individual variation has not to my knowledge been studied.

The various causes of tooth wear do not all affect the teeth identically, and some distinction among causes is clearly necessary for much to be done with the subject. There is a serious problem in that one cause can affect teeth in several ways and, conversely, that our imagination and observations of living peoples will probably not provide a complete inventory of even the important causes of attrition. The tooth material can be removed in flakes, in scratches, in an apparently smooth manner, and by solution. These can be of different intensities and affect cusps, individual teeth, and parts of the mouth differently. The difference between attrition of enamel and exposed dentine may be subject to variation among causes. It is conceivable that some items chewed may affect the normal reconstitution of enamel, either positively or negatively.

by G. H. R. von Koenigswald☆
Frankfurt, Germany. 27 xi 71

Among the teeth of *Sinanthropus*, so carefully described by Weidenreich (1937), there are two which show a kind of damage difficult to explain. One is a second upper molar (no. 145), not illustrated, the other an isolated left first molar (no. 38), of which we have a cast. Weidenreich reports (p. 163),

> This lower molar shows a strange indentation on its mesial and distal surfaces. The indentations are located just below the boundary of the enamel and occupy the greatest part of the neck region. The distal indentation is deeper, narrower, and shorter than the mesial one. Its length amounts to 6,8 mm, its breadth to 1,6 mm at its widest part. . . . It is interesting to note that the distal contact facet which partly forms the upper border of the indentation is so deep as to cause the enamel to be completely worn off within the entire lower part of the facet, even affecting the dentine. The mesial indentation shows similar conditions. . . . The mesial contact facet shows similar conditions and the same relation to the indentation as the distal one.

The same conditions have been described by Martin (1923) for the lower molars of La Quina man. The grooves are on the same side and in the same place as in the *Sinanthropus* molar; they are found on the first and second molars opposite each other on both sides of the mandible. There is no indication of tartar or caries. Says Weidenreich,

> Siffre (1911), a dentist, entrusted to make a special investigation, came to the conclusion that the indentations in question were lesions caused by the constant usage of toothpick. . . . He believes that the toothpick was in the form of a bone needle. . . . The idea that Neanderthal Man made regular use of a toothpick seems too grotesque to be true.

Weidenreich, after examining a number of arguments, comes to the conclusion (p. 164) that the "indentations, therefore, must be considered as a pathological condition of the tooth. . . . I believe it possible that these grooves could have resulted from a localized gingivites!"

Among our fossils from Sangiran is a single incisor of a buffalo in which on one side we find the same type of groove along the enamel border, only deeper and broader. There can be no doubt that the damage was caused by tough grasses' having slipped through the space between the teeth and rubbed against the neck of the tooth. The *Sinanthropus* molar in question is very much worn, even exposing the secondary dentine in places (stage 7 according to Weidenreich). In this state of wear the teeth can hardly have formed an uninterrupted row. I therefore suggest that tough fibrous material, intensively chewed, had repeatedly been pressed into the interstices between the teeth and then pulled out by hand, causing the grooves along the enamel border that we observe on the mesial and distal face of the *Sinanthropus* molar.

by Richard G. Wilkinson☆
Albany, N.Y., U.S.A. 24 xi 71

Molnar's optimism over the role of dental-attrition studies as a means of furthering our understanding of the "lifeways" of various human populations is surely warranted. This is especially true since the dentition provides us with the greatest amount of quantitative and qualitative data in skeletal populations. As Molnar points out, the systematic analysis of dental attrition is a relatively new field, and as such is in need of accurate, reproducible data-gathering techniques. The development of such techniques with regard to the form and direction of tooth wear is well under way, but the degree of wear may not be so readily quantifiable.

Molnar refers to the warnings of Brothwell and Rabkin against assuming a correlation between chronological age and degree of attrition. It certainly must be agreed that large differences in the degree of tooth wear between two populations are better explained through technology than longevity. If, however, we are dealing with populations similar in technology and/or subsistence pattern, the ages of the individuals in the samples might be of critical importance and an attempt must be made to insure that the ages of the individuals in the samples are equal. This may not present too formidable a problem when one is dealing with living populations, but in the case of skeletal populations it does.

We can compare prehistoric Illinois Indians of 35 to 45 years of age with a similar age group from a modern population and confidently assign differences in the amount of tooth wear to obvious differences in technology, simply because the differences will be great. If we want to compare two prehistoric Indian populations, the differences will be considerably less marked, and a 10-year age interval may mask a great deal of wear variability which is due to age alone. Current techniques for determining the age of individuals from skeletal evidence simply cannot segregate individuals into age categories small enough for comparative studies of the degree of dental attrition when technological variation is held relatively constant.

This difficulty would not appreciably affect the analysis of the form and direction of tooth wear, however, and it is in this area that we should be intensifying our efforts. Molnar has provided us with a good overview of the background of dental attrition studies and has suggested avenues for future research. What we need now is a formalized methodology and cooperation in the form of data publication.

by Milford H. Wolpoff☆
Ann Arbor, Mich., U.S.A. 23 xi 71

Molnar has written an excellent review of the literature concerned with variations in tooth use. I am particularly interested in the use of the anterior dentition as a holding device. Molnar reports the prying off of rusted gasoline-drum covers (De Poncins 1941) and other similar functions. I believe that the gripping and holding functions of the anterior dentition have had even greater selective advantage in the past. Table 1 indicates the distribution of averaged mandibular and maxillary anterior tooth-row summed lengths, breadths, and areas in fossil and modern hominids. It can be seen that the greatest change in the anterior teeth is in the breadth reduction which occurred after the Neandertals. In both mean value and range, the breadths of the anterior teeth in hominids up to and including Neandertals are close to the same and are about

TABLE 1

AVERAGED MAXILLARY AND MANDIBULAR ANTERIOR TOOTH-ROW SUMMED MESIODISTAL LENGTHS (L), BUCCOLINGUAL BREADTHS (B), AND AREAS (L*B)(mm)

	L				B				L*B			
	MEAN	RANGE	N	CV	MEAN	RANGE	N	CV	MEAN	RANGE	N	CV
Maxilla												
Australopithecines	26.3	22.7–29.0	10	7.1	24.7	21.4–28.6	20	8.1	216	183.4–238.8	8	9.1
Pithecanthropines	28.0	24.2–29.5	4	8.3	27.6	25.7–32.6	4	10.5	260	208.7–320.2	4	14.3
Neandertals	26.6	24.0–30.0	16	7.4	26.9	22.9–32.2	18	8.9	235	196.8–292.0	15	11.5
Anatomically modern *H. sapiens*	24.5	18.7–29.4	164	7.5	23.0	18.8–30.3	160	7.7	190	131.0–258.0	160	13.0
Mandible												
Australopithecines	20.3	17.2–23.0	14	7.8	23.0	20.0–26.5	13	8.6	160	129.6–197.1	13	13.3
Pithecanthropines	21.1	18.2–23.8	12	7.6	23.8	21.4–27.8	12	7.5	170	145.6–201.8	12	10.0
Neandertals	20.5	17.5–22.8	37	7.0	24.5	21.4–28.7	35	6.7	171	130.3–203.0	35	13.9
Anatomically modern *H. sapiens*	19.2	14.2–22.4	180	7.8	20.4	14.5–25.0	170	7.8	133	82.0–178.0	167	12.9

NOTE: N is the sample size and CV the coefficient of variation.

20% greater than in modern man. This difference is 2.20 in the maxilla and 2.60 in the mandible.

Greater breadth means far greater structural strength. If Eskimos can pry off rusted gasoline-drum covers with their (reduced) anterior teeth, one can imagine the regular use to which teeth of more ancient populations must have been put. When something is gripped in the teeth, providing a steady position for the mouth or applying linear or rotational force at the mouth requires, primarily, use of the nuchal musculature. Consequently, the extensive planum nuchale and broad occipital bases of premodern hominids are part of a morphological pattern that includes large anterior teeth and supporting facial architecture.

As Molnar points out, another indication of the intense selection for large (particularly, broad) anterior teeth is in the observed differential wear of incisors compared with molars. This occurs in both gracile (MLD 18, MLD 23) and robust (SK 52, SK 65) australopithecines, in pithecanthropines (OH 13, Ternifine 3), and in Neandertals (Qafzeh 5,8, Shanidar 2, Saccopastore 2, La Quina H5, Monsempron).

I believe the evidence indicates that reduction of the broad Lower and Middle Pleistocene anterior dentitions is a consequence of the development of numerous special-purpose tools by Neandertals, where previously fewer numbers of general-purpose tools had sufficed (Brose and Wolpoff 1971). The development of such special-purpose tools reduced selection for force and power in the anterior dentition through a combination of less strenuous use and use over shorter periods of time. For example, it takes far more time and effort for an apparatus operating essentially as a vise to hold a piece of wood when the wood is being cut in half with an all-purpose knife than when it is being cut with a saw. The concomitant reduction of the anterior dentition continued through the remainder of the Pleistocene and, on a worldwide basis, through the post-Pleistocene period (Brace and Mahler 1971).

by GARY A. WRIGHT☆

Albany, N.Y., U.S.A. 22 XI 71

Molnar summarizes data on two important facts: (1) human populations, both ancient and modern, particularly nonagriculturalists, may show extensive dental attrition, and (2) teeth, in some cultures, are widely employed as tools.

One thing that will be extremely helpful will be a major study of teeth as particular tools and the exact kind of wear produced by each utilization. It is not yet possible to draw all correlations of this nature, but here we find some in regard to chipping of teeth and certain tooth-tool functions, and the "prodigious development of the muscles of mastication" in Eskimos due to the chewing of hardened seal and walrus hides to soften them. Elsewhere Molnar notes that the Australian Aborigines use their teeth as a vise, to strip bark, to chew sinew, etc. He concludes that "all of these craft functions of the teeth can be expected to cause unique wear patterns." What are they?

The study of dental attrition also has implications for our ideas on human evolution, since individual tooth-size variations are often used as a major criterion for separating taxa of fossil hominids. After looking at interstitial wear and size variations among Lower Pleistocene hominids, Wolpoff (1971*b*:221) concluded that many of them seem to be born "as *Homo habilis,* grow up to be australopithecines, and if they live much past maturity die as *Homo erectus.*"

Brace (e.g., 1964) has argued that the major reason for the reduction of the forward part of the dental arch and the supporting parts of the face from Neandertal to Upper Paleolithic populations was technological refinement of tools, which reduced the significance of large and powerful anterior teeth. This argument has been discussed by Brose and Wolpoff (1971:1176), who submit that for Neandertals "the primary function of anterior teeth [as tools] is in gripping, holding, exerting torsion," etc. They find, for example, that the increased breadth of Neandertal anterior teeth was an effective means of structural refinement and that "even slightly worn Neandertal incisors tend to be almost square" (Brose and Wolpoff 1971:1176).

Studies such as these suggest that we now must go beyond the two facts of dental wear and teeth as tools and begin studying the relationship of particular functions of teeth and the resultant wear patterns, and then apply these data to major theoretical problems such as hominid evolution. Molnar's article is a useful start even though issues such as quantification of wear are left undiscussed.

Reply

by STEPHEN MOLNAR

I am gratified that so many of the commentators saw my paper as a commendable first step which opened up an important area of research. As several noted, the purpose of this paper was to raise questions about tooth wear, tooth function, and culture. Research opportunities abound in this rather neglected area, even though a substantial record already exists in the mass of skeletal remains of extinct and extant populations. All that is required is for numerous investigators to examine this material in some consistent, standardized way. The results, coupled with experimental studies and ethnographic observations, will go a long way towards understanding biocultural interactions.

In reference to Brian's comments, the wear pattern distinction between many fossil hominid and modern teeth is not at all clear. Patterns common to both groups occur as well as some striking differences, as I have tried to note. Two major factors should be kept in mind: First, there is no single pattern of wear that is common to *all* modern *sapiens,* just as there is no single pattern for fossil *sapiens* and his predecessors; attritional patterns vary from population to population and even between sexes (see Molnar 1971*a*). (On the matter of sexual dimorphism in tooth wear, I appreciate the observations by Kennedy and by Ganguly.) Second, too few observations of wear patterns for either modern or fossil populations have been offered, and most of these few are casual, subjective appraisals.

There are many studies of human prehistoric skeletal remains, but I have relied on only a few in putting together this paper. Most of these skeletal analyses note the condition of the dentition briefly, almost as an afterthought. Many months ago, when I first wrote this paper, I selected and quoted from those publications that I thought best illustrated the points I was trying to make. Had I the paper to rewrite, the bibliographic references would probably differ somewhat. However, it was never my intention to write a complete synthesis of all the available literature on prehistoric dentition.

The data on human dental attrition are meager, as Ganguly points out, but sufficient information nevertheless exists about environmental effects on the teeth to formulate hypotheses concerned with the interactions between culture, biology, and long-term evolutionary changes. Testing them is another matter; though the means exist, very few investigators have looked at the problem. The question of diet and hence adaptations of Early and Middle Pleistocene hominids has been around for a long time, together with numerous highly speculative arguments. This question can be investigated experimentally in the laboratory and need not continue to plague paleoanthropologists (see Brace and Molnar 1967, Molnar 1968*a, c*). Use of ethnographic observations together with careful studies of the skeletal evidence is an important part of the record of past adaptations, dietary and otherwise, which I have tried to show in this paper. My thanks to Brace, Brose, Frisch, Greene, and Wright for emphasizing this aspect and for stating that useful evolutionary information can be gained.

The investigation of man's masticatory apparatus is extremely difficult and many-faceted. The questions raised by the commentators all shed light on the broader scope of the problem. Some aspects of the problem I have pointed out, but a few, such as the several sources of tooth wear described by Turner, are entirely new perspectives to me. All aspects of tooth wear production need to be explored. I have looked at only one so far to any extent: the relationships between motions, forces, and occlusal wear. Another is the abrasive quality of kinds of diets; tooth usage and wear has only been touched upon, and I have been limited in my efforts in this area. A third area, potentially the most significant as an indicator of developmental and environmental conditions, is investigation of microstructural changes in the dentine and enamel.

I appreciate the observations on tooth use and sources of wear offered by Ganguly, Poirier, Kennedy, and Turner. In reference to Poirier's statement that different types of activities can have the same effects on the teeth and supporting structures, I would like to point out that this is the very reason for the careful and extensive collection of ethnographic data concerning diet and technology. True, the holding of vines, yucca fibers, leather, or even a pipe stem in the incisors may produce very similar wear. There will be, however, intergroup differences that reflect differences in technology to at least some degree. The aim should be to find out to what degree destruction of dental tissues is a reflection of all segments of technology.

Many sources of tooth wear are recognized, just as numerous variations in the condition of the arch affect patterns of wear on the occlusal surfaces. Eruption sequences (as noted by Greene), missing teeth, which place a heavier burden on the balance of the dental arcade, and disease, either tooth decay or bone inflammation, are factors that alter or create unique planes over the occlusal surfaces. This is why it is important to study teeth in situ whenever possible. In the case of missing teeth, I have observed that loss of molars causes the individual to use his incisors and canines in a way similar to molars in grinding tough abrasive foods. The result often is upper incisors worn in a concave, scooped-out manner, a wear pattern frequently found in molars. Tooth wear occurs anywhere along the arch, but attrition typically occurs more in certain regions than in others, and the shape of the wear planes differs, depending on the several factors listed above.

The effect of missing teeth on chewing motions is actually unknown. Presumably tooth loss will cause an alteration of chewing motions to some degree, since muscle contraction sequences and hence jaw movements are carried out at a preconscious level and chewing habits are developed in response to the oral condition. No data exist to demonstrate masticatory motion alteration. The oro-facial complex is potentially one of the most challenging regions or systems of primate anatomy to study and understand. As it stands now, masticatory biomechanics is a kind of "no man's land," with only a few publications dealing with man's oro-facial anatomy as a functional unit (see Sicher and DuBrul 1970).

I appreciate the comments and descriptions of the sequelae to tooth attrition offered by Barrett, which add materially to descriptions of environmental effects on the oro-facial complex. The attrition between teeth —interproximal wear—is an important factor in the maintenance of dental arch integrity. Loss of tooth crown length and subsequent shrinkage in arch length is a significant consideration (Begg 1954, Hunt 1959, Wolpoff 1971*b*). Not only are there changes in the arch dimensions, but also pathological side effects can occur due to intertooth movement and wear. However, it is the occlusal surface pattern that varies from population to population in response to various uses of the teeth and dietary differences.

For some time I have been struck by the co-occurrence of extensive wear and many associated bone lesions, as described by Barrett, and early age at death. I have tried without success to get medical or dental experts with whom I have discussed the matter to speculate that these oro-facial pathologies might be a major contributor to an early death. Gejvall's comment that severe attrition and the sequelae of infection were probable causes of death is therefore most welcome.

Significant among the variables of tooth wear are the properties of the tooth tissues themselves. The chemical composition of the substances chewed is also likely to influence the rate of wear, as pointed out by Van Valen and Dewey. Only a few studies, of a limited nature, have been carried out to investigate this question of changes in the oral environment. It is useful, therefore, to learn of the investigations described by Van Valen which report a constant rate of enamel loss in bats and laboratory rats.

During my work on tooth wear, I came across several excellent papers on the microstructural quality of teeth (Bradford 1960, Kraus 1969, Nalbandian, Gonzales, and Sognnaes 1960, Sognnaes 1956). Sognnaes proposed that the tooth is a sensitive indicator of the developmental quality of the organism and especially of the calcifying properties of the diet. Kraus agreed and pointed out that the extended embryonic period of tooth development makes tooth microstructure a vital record of many life crises. Taking these observations as a lead, I proposed to look at the tooth as an organ that is highly adaptive and capable of responding to a variety of environmental stresses. Among these is, of course, mechanical stress and the resulting abrasion, with the deposition of secondary dentine as part of the response sequence. Other responses can be seen upon examination of the microstructure of the dentine—principally sclerosis of dentinal tubules, as I have reported elsewhere (Molnar 1971*b*, Molnar and Ward n.d.).

These changes in dentine will affect the rate of wear, but individual capacity to respond, or, rather, the state of a person's mineral metabolism, is the critical factor, so Gejvall's comments are very appropriate for a paper on dental attrition. In particular, I think his description of the lack of secondary dentine in the Westerhus population is especially significant, and the speculation that hypomineralization (due to D-avitaminosis or ?) may be one of the underlying causes should be carefully noted. Gejvall also describes the appearance in this population of Harris lines in tibiae. In my opinion, the quality of hard tissues can provide invaluable information about diet, disease, and the general state of health of the individual and hence the ecological position of the whole population. The teeth are especially sensitive indicators of the many environmental variables that affect mineralization in the system. Microstructural analysis together with dental attrition studies can provide vital records if only we can learn to read them, and these records are of considerable time depth, a condition which is lacking in studies of so many other biological features.

My work, which started with investigations of human chewing motions and experimentally produced wear patterns, has now led to the problem of discrete changes in tooth enamel, dentine, and cementum. This paper discusses only a single facet: gross structural changes in response to cultural factors. I hope the reader, like the commentators, will appreciate the numerous interrelated factors involved in dental-environmental relationships. The challenge is there, the research possibilities are endless, and the returns in terms of information about evolutionary processes are very great. More work is needed in all areas discussed in the paper, the comments, and this reply.

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AUSTRALIAN NATIONAL UNIVERSITY

Applications are invited for appointment to the foundation Chair of Anthropology in the Faculty of Arts. It is hoped that the appointee will be able to take up duty in 1973.

The Chair will be located within a Department of Prehistory and Anthropology. Courses in prehistory were established in 1972 under Professor D.J. Mulvaney. Arrangements for the headship of the department will be determined by the University in consultation with Professor Mulvaney and the Professor of Anthropology. It is envisaged that the department will develop integrated courses emphasising the prehistory, social organisation, and material culture of preindustrial societies, with particular emphasis on the Pacific area, including Australia. Prospective applicants should possess experience in the traditional fields of social and cultural anthropology, but should also have positive interest in developing the teaching of evolutionary and ecological aspects of man, his culture, and his environment, particularly of small-scale societies.

The salary for the post is $A15,369 per annum. The University provides reasonable travel and removal expenses and assistance with housing for an appointee from outside Canberra. Superannuation is on the FSSU pattern with supplementary benefits. Financial assistance towards study leave is also available.

The University reserves the right not to make an appointment or to make an appointment by invitation at any time.

Further information and the forms which should accompany an application may be obtained from C. G. Plowman, Academic Registrar, P.O. Box 4, Canberra, ACT 2600, Australia.

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■ The Chicago Folklore Prize is supported by an endowment established by the International Folklore Association and is awarded annually by the University of Chicago for an important contribution to the study of folklore. Students, candidates for higher degrees, and established scholars may compete for the prize. The contribution may be a monograph, a thesis, a dissertation, an annotated and interpreted collection of materials, or, in exceptional cases, a textbook. (Articles in periodicals or very brief monographs cannot be considered.) No restriction is placed on the choice of topic or material: the term "folklore" is used in its broadest sense (e.g., American, European folklore, etc.; anthropological, literary, religious folklore, etc). Entries, written in any of the major Western languages, are welcomed from any country in the world.

Material which has appeared in print may be submitted within one year from the time of publication. If the contestant wishes to have his entry returned, he should include the return postage. The successful contestant will be asked to donate his entry, if it is already printed, to the University of Chicago; if an award goes to an entry submitted in typed form, the author is requested to send a copy to the University of Chicago if it is later published.

The prize provides a cash award of about $75. If the entries merit special consideration and funds are available, more than one prize may be awarded; on the other hand, the judges may recommend that no award be made in a given year. Former prizewinners will not normally be eligible to win the prize a second time; however, those who have received an honorable mention will continue to be eligible to win a prize.

The 1972 prizewinners are as follows: First prize, Eleanor R. Long (Santa Clara, Calif., U.S.A.), for her book *"The Maid" and "The Hangman": Myth and Tradition in a Popular Ballad;* second prize, Ruth Firestone (Boulder, Colo., U.S.A.), for her dissertation *Elements of Traditional Structure in the Couplet Epics of the Late Middle High German Cycle,* and John I. Kolehmainen (Tiffin, Ohio, U.S.A.), for his manuscript *The Kalevala;* honorable mention, Charles C. Adams (Chico, Calif., U.S.A.), for his book *Boontling: An American Lingo,* and Marion D. De B. Kilson (Lexington, Md., U.S.A.) for her book *Kpela Lala: Ga Religious Songs and Symbols.*

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