

DENTAL MORPHOLOGY AT GUA CHA, WEST MALAYSIA, AND THE IMPLICATIONS FOR "SUNDADONTY"

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ABSTRACT

Both the Hoabinhian and the Neolithic series from Gua Cha, West Malaysia, diverge from recorded samples of recent Southeast Asians in their dental morphology. Their closest affinities instead lie with the prehistoric Jomon of Japan and various Pacific populations. Extended statistical analysis suggests that the Neolithic and earlier inhabitants of West Malaysia shared an ancient common ancestry with the Jomon on the one hand, and with populations in a ring around the Indian Ocean on the other hand. These groups exhibit variations on a widespread, ancestral dental morphology which evidently persisted in at least some parts of West Malaysia until Neolithic times. Any substantial immigration into the Malay Peninsula, associated with establishing the gene pool of any "Orang Asli" Aboriginal group or the Malays, would either have occurred far away from Gua Cha or would have postdated the Neolithic.

INTRODUCTION

Dental morphology, i.e. variation in the anatomical features of the crowns and roots as opposed to metrical variation, appeals to biological anthropologists interested in reconstructing population relationships for the reasons discussed by Scott and Turner (1997). Considerable evidence points to strong polygenic control over dental morphological expression, especially incisor shovelling and Carabelli's trait. There is little evidence that any particular trait, such as the shovelled incisors of East Asian and American Indians, confers any selective advantage, and hence dental morphology should be independent of environmental adaptation. There is virtually no evidence of sexual dimorphism in dental morphology, so males and females (and unsexed teeth) can all be pooled for analysis. Finally, hypotheses on relationships

among present-day populations can be tested on archaeological series, especially as teeth are often the best-preserved part of the skeleton.

Developing on previous work, Turner (1983) coined the term "Sundadonty" to refer to the common dental morphological pattern found among the indigenous "Southern Mongoloids" of Southeast Asia, Polynesia and Micronesia. This pattern is intermediate between the morphologically more complex Sinodont profile of Northeast Asia and the New World, and the simpler dental expressions found in Africa, Europe, and Melanesia. Subsequently, Turner (1987) pooled teeth from several prehistoric sites in Indonesia and Malaysia, including Gua Cha in West Malaysia ("8" in Figure 1), into an "Early Malay Archipelago" sample. This sample showed few clear differences from recent Island Southeast Asian teeth, which suggested to Turner that Sundadonty had been established in Southeast Asia by the late Pleistocene.

In a later study Turner (1990) found that Australian Aboriginal and recent Southeast Asian teeth looked remarkably similar, even though Melanesians could be clearly distinguished from Southeast Asians. Turner interpreted this result as further evidence for the late Pleistocene development of Sundadonty and, hence, the effective falsification of theories of a population replacement in Southeast Asia during the Holocene, especially those versions which propose a "Neolithic Mongoloid" immigration (e.g. Jacob 1967; Brace 1978; Bellwood 1993, 1997). Indeed, Turner (1992; Scott and Turner 1997:305) hypothesizes that anatomically modern *Homo sapiens*, originally characterized by a dental morphological pattern which could be labelled "proto-Sundadont", arose in Southeast Asia before spreading out across the world.

Several objections can be brought against Turner's interpretations. First, his 1987 paper used an Early Malay Archipelago sample dominated by Neolithic or younger teeth, as discussed below. According to the immigration theories of Brace and Bellwood, Neolithic and younger teeth should generally represent the replacing Mongoloid population, and so should indeed resemble recent Southeast Asian teeth. For Turner to find against a Neolithic immigration scenario, on the basis of dental morphology, he would need to demonstrate that the Sundadont pattern was already established with the pre-Neolithic dental material. Second, his 1990 paper which found a similarity between Australian Aborigines and recent Southeast Asians considered only eight dental traits. Even if the comparison were valid, it would still be possible that Mongoloid immigration and admixture had shifted Southeast Asian teeth from a pre-Neolithic, non-Sundadont, Melanesian-like pattern to a Sundadont (including Australian-like) pattern. Finally, neither paper attempted any multivariate statistical analysis, although this has been remedied in later studies (e.g. Turner 1992; Scott and Turner 1997).

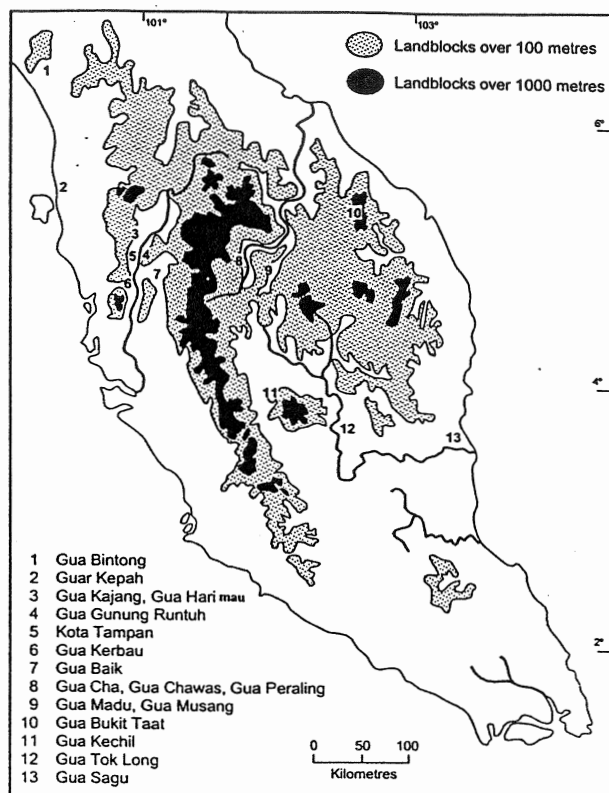


Figure 1. West Malaysia – topography and major prehistoric sites.

Further discussion of Turner's prehistoric Island Southeast Asian samples is warranted. His largest sample comes from Leang Codong in Sulawesi, which he calls Leang Tjadang in Celebes, and treats as a pre-Neolithic series dating to approximately 4000 BP (Turner 1990:302). However, the excavation of Leang Codong recovered numerous Early Metal Phase items, such as an iron spearhead, bronze leaf, and beads of glass and stone, which would appear to have been grave goods buried with the human remains (Bulbeck 1992:445; 1996-7:1026). After removal of Leang Codong, the remaining "Early Malay Archipelago" teeth are consistently less "Mongoloid" than any recent Southeast Asian sample (see Turner 1990: Figs 1 to 8). Even then, the pre-Neolithic status of this pared-down Early Malay Archipelago sample remains problematical. The number of Neolithic burials at Gua Cha approximately equals the number of Hoabinhian burials (Table 2, this paper). The teeth studied by Turner from "Gua Kepah" (correctly Guar Kepah, "2" in Figure 1) may be early Neolithic, or transitional between the Hoabinhian and the Neolithic (Bulbeck 1996:41). Turner's teeth from Sampung, in East Java, constitute a miniscule sample from a site that combines Mesolithic and Neolithic cultural remains in a confusing sequence (see Van Heekeren 1972:94-98; Storm 1995:25; Bellwood 1997:197). And Turner's Flores sample involved very few skulls which, moreover, derive from a transitional zone between Island Southeast Asia and Melanesia in terms of human osteology (see Storm 1995).

Gua Cha is Turner's only site with distinct, substantial pre-Neolithic and Neolithic series in a location suitable for evaluating his claims for the pre-Neolithic establishment of Sundadonty. Unfortunately, there is the complication that Gua Cha lies near the traditional haunts of the Semang and the Senoi, whose dental morphological profile has not yet been recorded and which may well differ from the general Southeast Asian profile. According to Bellwood (1997:85, 265), the Semang Negritos are direct descendants of the Hoabinhian hunter-gatherers, while the Senoi probably also retain some of the original, pre-Neolithic gene pool. Further, Bellwood is non-committal on the extent to which the Gua Cha Neolithic remains should represent the ancestors of the Semang and/or the Senoi. Hence, in this special case, the Gua Cha Neolithic teeth need not necessarily demonstrate the immigrant "Mongoloid" morphology that Bellwood would expect of most samples of Southeast Asian Neolithic teeth. Nonetheless, while Bellwood's reservations could accommodate lack of dental morphological change over time at Gua Cha, they would be inconsistent with

the Hoabinhian teeth evincing a "Mongoloid" morphology. If the Gua Cha Hoabinhian teeth appear to be Sundadont, then Turner's argument against late Holocene population replacement in Southeast Asia would still stand.

I have now had the opportunity to observe all of the extant Gua Cha skeletal material personally, including the Hoabinhian and Neolithic specimens held at Cambridge University. The first task of this paper will be to report the dental morphology of these two series, since Turner has not published any separate account of the Gua Cha teeth, and since Trevor and Brothwell (1962) ignored dental morphology altogether in their description of the Gua Cha remains. The paper will then review Gua Cha's relevance to Turner's concept of Sundadonty and to our understanding of population change in West Malaysia.

MATERIALS: THE GUA CHA HUMAN REMAINS

Gua Cha is a large, spacious limestone shelter located deep in the interior of the Malay Peninsula, on the Sungei Nenggiri, at approximately 100 metres above sea-level. Two main phases are recognized: the Hoabinhian, characterized by habitation and occasional burials; and the Neolithic, when the site apparently functioned as a cemetery (Sieveking 1987:81-84). The stratigraphic sections do not seem to display any sterile layer which might correspond to a lengthy abandonment between the Hoabinhian and the Neolithic layers. However, these layers were recognized as quite distinct in both the original 1954 excavation by Sieveking, and the 1979 re-excavation by Adi and Bellwood (Adi 1985). The Neolithic burials typically included fine pots, polished stone implements, polished stone bangles, and jewelry made from marine shell. The pottery could be assigned to the Ban Kao culture, by comparison with similar wares from the Ban Kao site in south-central Thailand (e.g. Bellwood 1993). The Hoabinhian burials lack any of these goods, and the only recognized grave goods are simple furnishings such as a stone pillow for the head (Sieveking 1954; Adi 1985). A further contrast is the extended orientation of the Neolithic skeletons compared to the Hoabinhian burials which, if they are not anatomically disturbed, had the knees flexed towards the waist. As Table 1 shows, the association between an extended skeleton and Neolithic grave goods is, statistically, strong and highly significant.

The sketches and photographs in Sieveking (1954) show that he excavated numerous skeletons, nearly 40 in all, often in good condition. Sadly, however, only about two-thirds of the cranial material made it to the Duck-

worth Laboratory, Cambridge University, whither Sieveking sent it, and very little of the postcranial material arrived (Bulbeck n.d.). In relating the material that did arrive to Sieveking's records, the Duckworth Laboratory staff apparently made some mismatches. As I argue elsewhere (Bulbeck n.d.), some of the supposedly Neolithic As.33.5... specimens (see Trevor and Brothwell 1962) should be re-assigned to the Hoabinhian, and some of the As.33.6... specimens should be re-assigned to the Neolithic, as listed in Table 2. After these adjustments, the percentages of nitrogen in the Neolithic bone samples assayed by Kennedy (1964) fall within a tight range of 0.22-0.25. The assayed Hoabinhian bone samples show less nitrogen, conforming to the expectation of a loss of nitrogen over time, and exhibit a wide range of values, suggestive of burials over a much longer period (Table 3).

Table 2 also includes the three Hoabinhian burials, labelled Gua Cha 1, 2 and 4, which Adi and Bellwood excavated in 1979, and which I recorded in my MA thesis (Bulbeck 1981). The addition of these specimens, unavailable to Turner, produces approximately equal numbers of reliable observations on the Hoabinhian and the Neolithic teeth.

A charcoal sample from the Hoabinhian layers, immediately beneath the transition to the Neolithic layers (ANU-2217), is radiocarbon dated at 3020 ± 230 BP (Abaz Alimanovic pers. comm.). This calibrates to 2880-3440 BP (intercepts at 3210, 3230, and 3240 BP) at one sigma, or 2710-3730 BP at two sigma (cf. Stuiver and Reimer 1993). It suggests 3000 BP as the approximate dating of the Neolithic cemetery, for various reasons. Extended burials and/or pottery similar to that at Ban Kao appeared widely across southern Thailand and West Malaysia between approximately 3000 and 4000 BP (Bellwood 1993:46-48; Higham and Thosarat 1998:44-87). The tight range of the nitrogen concentrations in the assayed Gua Cha Neolithic samples (Table 3) is consistent with a short lapse of time, less than a millennium. There are no grave goods with the Neolithic burials which might be suggestive of a post-2500 BP dating (e.g. no traces of metals, or Indian or Chinese goods).

The chronology of the Hoabinhian burials, however, is less secure. Adi (1985) suggests occupation at Gua Cha may have started as early as 10,000 years ago, but the evidence from radiocarbon dating is equivocal. Although a charcoal sample from the middle of the Hoabinhian deposits returned a date of 6300 ± 170 BP, the available sample from the base of the deposits (ANU-2219) clocked in at only 3790 ± 250 BP (Peter Bellwood pers. comm.), and hence was discounted as contaminated by

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Table 1. Comparisons of burial mode and grave good associations (after Bulbeck n.d.)

	Extended Burials	Flexed Burials	Sub-total	Non-Extended Burials	Total
Neolithic Grave Goods	20	0	20	1	21
No Neolithic Grave Goods	1	9	10	18	19

Extended versus flexed burials compared with presence/absence of grave goods: Fisher Exact Test (Startup and Whittaker 1982:137-38), $p = 0.0000008$.

Extended versus non-extended burials compared with presence/absence of grave goods: Chi-square = 32.53, 1 degree of freedom, $p < 0.005$. Phi-square = 0.81 (very strong).

Note: Non-extended burials include flexed and anatomically disturbed burials. The Fisher Exact Test is employed for the contingency table involving flexed burials because the Chi-square test can be applied only when at least 80% of the expected frequencies equal or exceed five (Startup and Whittaker 1982:134). This criterion is met only with the contingency table involving non-extended burials. The Phi-square coefficient achieves its maximum possible value of 1 only when there is a perfect association between the two compared attributes (Startup and Whittaker 1982:139-140).

Table 2. Osteologically recorded Gua Cha sample (after Bulbeck n.d.)

Specimen	Cultural Association	Status	Observed Remains
Gua Cha 1	Hoabinhian	Male adult	Teeth, jaws, cranial + postcranial fragments
As.33.6.11	Hoabinhian	Male adult	Complete skull
As.33.6.5A	Hoabinhian	Male adult	Teeth, jaws, cranial fragments
As.33.6.6	Hoabinhian	Male adult	Teeth, jaws, cranial fragments
As.33.6.7A	Hoabinhian	Male adult	Teeth, jaws, partial face
As.33.6.7B	Hoabinhian	Male adult	Teeth, partial mandible
As.33.6.8	Hoabinhian	Male adult	Teeth, jaws, cranial fragments
As.33.5.9	Hoabinhian	Male adult	Fairly complete calvarium
As.33.6.1	Hoabinhian	Male adult	Partial calvarium
As.33.5.4	Hoabinhian	Male adult	Right knee joint area
As.33.6.4	Hoabinhian	Female adult	Teeth, jaws, partial face
As.33.6.9	Hoabinhian	Female adult	Teeth, jaws, facial fragments
As.33.5.6	Hoabinhian	Female adult	Calvarial fragments
As.33.6.5B	Hoabinhian	Female adult	Teeth, mandible, cranial fragments
Gua Cha 4	Hoabinhian	Female adult	Pelvis and leg bone fragments
Gua Cha 2	Hoabinhian	Teenager	Teeth + postcranial fragments
As.33.5.1	Neolithic	Male adult	Complete skull
As.33.5.10	Neolithic	Male adult	Teeth, jaws, face, calvarial fragments
As.33.6.3A	Neolithic	Male adult	Teeth, jaws, facial + postcranial fragments
As.33.5.2	Neolithic	Male adult	Teeth, mandible, calvarial fragments
As.33.6.2	Neolithic	Male adult	Teeth, mandible
As.33.5.4	Neolithic	Male adult	Foot bones
As.33.5.5	Neolithic	Male adult	Teeth, jaws, cranial fragments
As.33.6.10	Neolithic	Male teenager	Teeth, mandible, calvarial fragments
As.33.5.3	Neolithic	Female adult	Complete skull + Trevor's postcranial data
As.33.5.8	Neolithic	Female adult	Teeth, jaws, partial cranium, humerus fragment
As.33.6.3B	Neolithic	Child	Teeth, jaws
As.33.5.7	Neolithic	Child	Teeth

Table 3. Nitrogen concentrations in Gua Cha bone samples (adapted from Kennedy 1964)

Burial No.	Cultural Association	% Nitrogen	Stratigraphic Position	Type of Burial
31 [16]	Neolithic	0.25	Buried into Hoabinhian layers	Extended
8	Neolithic	0.24	Buried into Hoabinhian layers	Extended
10	Neolithic	0.22	Neolithic layers	Extended
14	Hoabinhian	0.20	Hoabinhian layers	Flexed
21	Hoabinhian	0.20	Lower Hoabinhian layers	Flexed
19	Hoabinhian	0.18	Lowermost Hoabinhian layers	Incomplete primary
23	Hoabinhian	0.17	Uppermost Hoabinhian layers	Incomplete primary
29	Hoabinhian	0.11	Below Neolithic layers	"Ritual deposition"

Note. The burial number in square brackets is Kennedy's label which, as shown in Bulbeck (n.d.), cannot be correct. Burial numbers and archaeological data come from Sieveking (1954) except where reinterpreted in Bulbeck (n.d.).

younger carbon (Adi 1985). Even if the approximately 1.5 metres of deposits did permit us to posit a circa 10,000 BP onset for habitation at Gua Cha, there would be no reason to assume the burials had begun at such an early period. The range of nitrogen concentrations (Table 3) may suggest that the Hoabinhian burials had spanned several millennia, but this need not take us back beyond the middle Holocene. John Krigbaum (pers. comm.) has taken samples for AMS radiocarbon dating which might presently allow the chronology of the Gua Cha burials to be better understood. For the time being, I conservatively assume the Gua Cha Hoabinhian burials were broadly middle Holocene.

In cases of such dramatic change in material culture and burial practice as had occurred at Gua Cha, archaeologists can be tempted to assume the arrival of "new people". At the very least we would infer the infusion of some newcomers at the Hoabinhian/Neolithic junction, even if the Neolithic Gua Cha population primarily derived from a basal stock which included the Gua Cha Hoabinhians. Arguably the Neolithic burials should disproportionately represent any newcomers, compared to the general surrounding population, given the association of the burials with prestigious and frequently exotic grave goods. On the other hand, outsiders who married into the local population may have originated from osteologically similar populations, in which case there need be no disjunction between the Gua Cha Hoabinhian and Neolithic skeletal traits. In summary, the Gua Cha Neolithic human remains should be a sensitive indicator of any human osteological transition which had occurred in the Malay Peninsula hinterland at the Neolithic boundary. Lack of evidence of Hoabinhian/Neolithic contrasts would suggest either that there was a minimal influx of newcomers associated with the hinterland Neolithic, or

that the inhabitants of the Malay Peninsula were relatively homogeneous, in terms of their skeletal morphology, until as recently as c. 3000 BP.

METHODS

All of the observable Gua Cha teeth at Duckworth Laboratory, Cambridge University, were examined between 2 and 11 October 1996. I recorded the trait expressions according to the Arizona State University (ASU) system wherever I could, including reference to the standard plaques produced by Turner and his colleagues (Scott and Turner 1997; see also Hillson 1996). Unfortunately, traits had often been obliterated owing to occlusal wear, chipped enamel or caries, so the available sample sizes are usually small. The observed occurrences were entered into a Borland "Reflex" computer program, which was utilized to count up the frequencies of the various trait expressions. The data are reported for both sexes combined, because dental morphological variation lacks significant differences between the sexes (Scott and Turner 1997). In the "Results" section below, as well as in Appendix 1, underlining indicates that a tooth in the upper dental arcade is referred to, whereas absence of underlining connotes a tooth in the lower arcade.

The available Gua Cha Hoabinhian sample was boosted by the inclusion of my previous observations on Gua Cha 1 and 2 (Bulbeck 1981), plus a few isolated teeth found among the matrix of these burials. These observations were made in terms of the systems that were then current, such as Dahlberg's grades for incisor shovelling, before Turner and his colleagues had established all the details of their ASU system and begun distributing the standard plaques. The inclusion of these observations in the present data base involved some degree of translation between the ASU and pre-existing systems. This

procedure followed the guidelines in Scott and Turner (1997), along with reference to enlarged photographs of the Gua Cha 1 dental arcade taken before Gua Cha 1 and 2 were returned to Kuala Lumpur.

When the available sample sizes are small, Scott and Turner (1997:238-42) recommend trait-by-trait comparison of the observed incidences with those previously recorded on a worldwide basis and found to discriminate well between major groups. In this particular case, the implications were not fully clear, so I also applied Smith's Mean Measure of Divergence (MMD) statistic, as suitably modified for small samples (Johnson and Lovell 1994). Finally, in the few cases where the Gua Cha Hoabinhian and Neolithic incidences contrast starkly, and sample sizes are not pitifully small, I tested for statistically significant differences using the Fisher Exact Test (Startup and Whittaker 1982:137-138) and the Chi-square test, with p set at the conventional value of 0.05.

RESULTS

Polymorphic variation was not observed in approximately one quarter of the traits. All lower incisors and upper canines showed an absence of shovelling (8 Hoabinhian I1, 7 Hoabinhian I2, 7 Hoabinhian C, 6 Neolithic I1, 5 Neolithic I2, 5 Neolithic C). All upper incisors and canines showed absence of double shovelling (5 Hoabinhian I1, 5 Hoabinhian I2, 7 Neolithic I1, 4 Neolithic I2, 8 Hoabinhian C, 5 Neolithic C). No central incisors showed any winging (9 Hoabinhian I1, 11 Hoabinhian lower I1, 4 Neolithic I1, 4 Neolithic lower I1). None of the eight Hoabinhian or the five Neolithic upper lateral incisors were pegs or other odd variants. Nor did any of the seven Hoabinhian or five Neolithic upper canines have a mesial ridge. All seven Hoabinhian and five Neolithic lower canines sported a single root. No premolars had an odontome (1 Hoabinhian P1, 2 Hoabinhian P2, 4 Hoabinhian lower P1, 4 Hoabinhian lower P2, 6 Neolithic P1, 6 Neolithic P2, 7 Neolithic lower P1, 8 Neolithic lower P2). Neither the single Hoabinhian case nor the four Neolithic cases could be classified as Uto-Aztecan first upper premolars. Neither the nine Hoabinhian nor the two Neolithic first lower premolars exhibited a Tomes' root. All upper molars were three-rooted (Hoabinhian 6 M1, 5 M2, 7 M3; Neolithic 3 M1, 3 M2, 4 M3). Finally, very minor deflecting wrinkles (grades 1 or 2, i.e. less than 3) were observed on the two Neolithic M1, the single Hoabinhian M2, and the single Neolithic M3.

Appendix 1 presents my dental morphological observations whenever the Gua Cha Hoabinhian or the Neo-

lithic observable cases proved to be polymorphic. In almost all cases, the recorded Hoabinhian and Neolithic expressions appear similar or, at least, apparent differences would seem to reflect miniature sample sizes. In only one case does the difference register as statistically significant.¹ Lower M2 enamel extension scores 0 on 0 Hoabinhian cases and 4 Neolithic cases, compared to 1-2 on 13 Hoabinhian cases and 6 Neolithic cases; Fisher Exact Test, $p = 0.024$. Hence the Hoabinhian second lower molars evince more frequent enamel extension which, according to Scott and Turner (1997:204-206), is a characteristic trait of East Asian and New World populations. The biological significance of this difference is hard to evaluate; even if the Hoabinhian and Neolithic samples had been drawn from exactly the same population, sampling error alone would be expected to simulate occasional "statistically significant" differences, given the large number of dental traits under review.

SOUTHEAST ASIAN TEETH ON A GLOBAL SCALE

Before the Gua Cha trait frequencies can be compared with those of other populations, we should consider the overall patterning of human dental morphological variation. Here we refer to the Nei distances, based on 23 crown and root traits, reported by Scott and Turner (1997:Appendix A) for 21 composite populations. I will also employ these data to illustrate my "seriated dendrograms" and "*inter alia* derivatives", and their implications for understanding worldwide human dental variation. Note that Turner's observations on Gua Cha are included here in the "prehistoric Southeast Asia" sample, but their role is minimal compared to the contribution made by the predominantly Neolithic, Bronze and Iron Age teeth from Thailand, Laos and Vietnam as well as from Malaysia and Indonesia.

There is much debate on how best to treat biological distances in portraying biological relationships within a species, such as *Homo sapiens*. Were different species involved, the choice would be easier. A large body of literature recommends maximum parsimony (or Wagner) trees, with or without the graded expressions partitioned into segments, with or without reference to a nominated "outgroup" (e.g. Farris 1972, 1977; Chappill 1993). The display of relationships then becomes a matter of producing the phylogenetic tree which involves the fewest evolutionary reversals (homoplasies) and which does not make the questionable assumption of constant evolutionary change along every line. This approach is also ideal for producing biological classifications for two reasons. First, the clusters bunch together those species which share a unique array of diagnostic features. Second, any

two species which cluster to the exclusion of a third species do so through hypothetically sharing a common ancestry which excludes the third species (Farris 1977; Wiley 1981).

However, as Fix stresses in his contribution to this volume, the underlying model of fission and divergence, which would be appropriate for comparisons between species, is dubious or just plain wrong when comparing populations within a species. In these latter cases, where genes flow between the comparative groups, the assumptions made by maximum parsimony trees are clearly inappropriate. Additionally, trees produced by hierarchical clustering might also appear misleading, because they have a single leading stem which superficially simulates a common ancestor, while each subsequent branching could be easily read as a split between descendant populations. Nonetheless hierarchical clustering has certain attractions, even for populations within a species, compared to other graphic techniques for displaying biological distances. Two- or three-dimensional scattergrams leave it up to the reader's eye to decide which groups actually form distinct clusters, and which of these clusters would be most closely approached by some other, more isolated sample. Maximum likelihood trees (e.g. White 1997:Fig 4.3h) also leave the matter of cluster associations somewhat open. By contrast, hierarchical clustering specifies the clusters, and gives an unambiguous answer to questions such as "Is X or Y more similar to Z?" (given the assumptions employed in the analysis).

This would appear to be Scott and Turner's (1997) justification to analyze their dental morphological distances with the "unweighted pair group means analysis" (UPGMA), an arithmetically simple version of hierarchical clustering. Scott and Turner are not attempting to classify *Homo sapiens* into discrete dental morphological groups, each with its unique common ancestry. Rather, they wish to explain the similarities and differences in dental morphology within and between the continents and island worlds. They proceed by pooling morphologically similar samples into geographically coherent macro-populations, and inferring that genetic similarity reflects the interwoven combination of shared ancestry and long-term gene flow. Their discussions of population history are based on (1) morphologically anomalous samples within what are, otherwise, relatively homogeneous geographical groupings, and (2) large-scale relationships between the macro-populations. (Note that my dendrograms in this article link up from left to right, rather than the usual right to left direction, to emphasize the interpretation of hierarchical clustering as an exercise in successive pooling.)

I recommend the seriation of dendrograms as an extension of Scott and Turner's general approach to illustrating intra-specific relationships. Without disrupting the hierarchically displayed clusters, seriation simultaneously shows relationships that extend beyond them, in the same way that scattergrams do. My Figure 2 differs from Scott and Turner's own UPGMA tree (Fig. 7.5) only in the order in the arrangement of the groups. The arrangement in Figure 2 maximizes the degree to which biologically similar samples are placed adjacently, and biologically distant samples are placed far apart. Dental samples which are morphologically very different from Sinodonts, especially the South African San, New Guinea, and Europeans, are pushed to the top of the tree. Dental samples which morphologically resemble Sinodonts, the Polynesians, Micronesians, Southeast Asians, Jomon (pre-Yayoi Japanese), and South Siberians, are positioned increasingly closer towards the Sinodont cluster. Hence the tree retains the major contrast between Sinodonts and others, but grades these others from very unlike Sinodonts (Africa, New Guinea, Europe) to Sinodont-like. In terms of the original half-matrix of biological distances, the placement of small distances near the diagonal is maximized, as is the positioning of large distances away from the diagonal (Table 4). Indeed the order shown here is consistent with 91.7% of the variation involved in the original battery of distances. The arithmetic procedures for seriating the dendrogram, and calculating the resultant "goodness of fit", are explained elsewhere (Bulbeck 1993, 1997).

Seriation also ameliorates what might otherwise be anomalous results in the analysis. Turner (e.g. 1990) has long placed the Jomon, along with Polynesians, Micronesians and Southeast Asians, into the "Sundadonts". Indeed, the Jomon's smallest Nei distances are with Polynesians and prehistoric Southeast Asians (Table 4). However, the latter have even smaller Nei distances from other groups with large Nei distances from the Jomon. Hence the Jomon are left to link up with South Siberians, while the other Sundadonts link up with Australians, Melanesians, and then South and West Africans. Now, seriation correctly shows that the Jomon are indeed very close to Sunda-Pacific groups (Southeast Asians, Polynesians, Micronesians) as a matter of a similarity expressed across sister clusters. This is not an isolated result: whereas hierarchical clusters tend to be quite unstable, which is one of the main arguments against their use (e.g. Farris 1972), repeated trials have convinced me that seriated orders tend to be stable. The *inter alia* derivatives can illustrate my point here.

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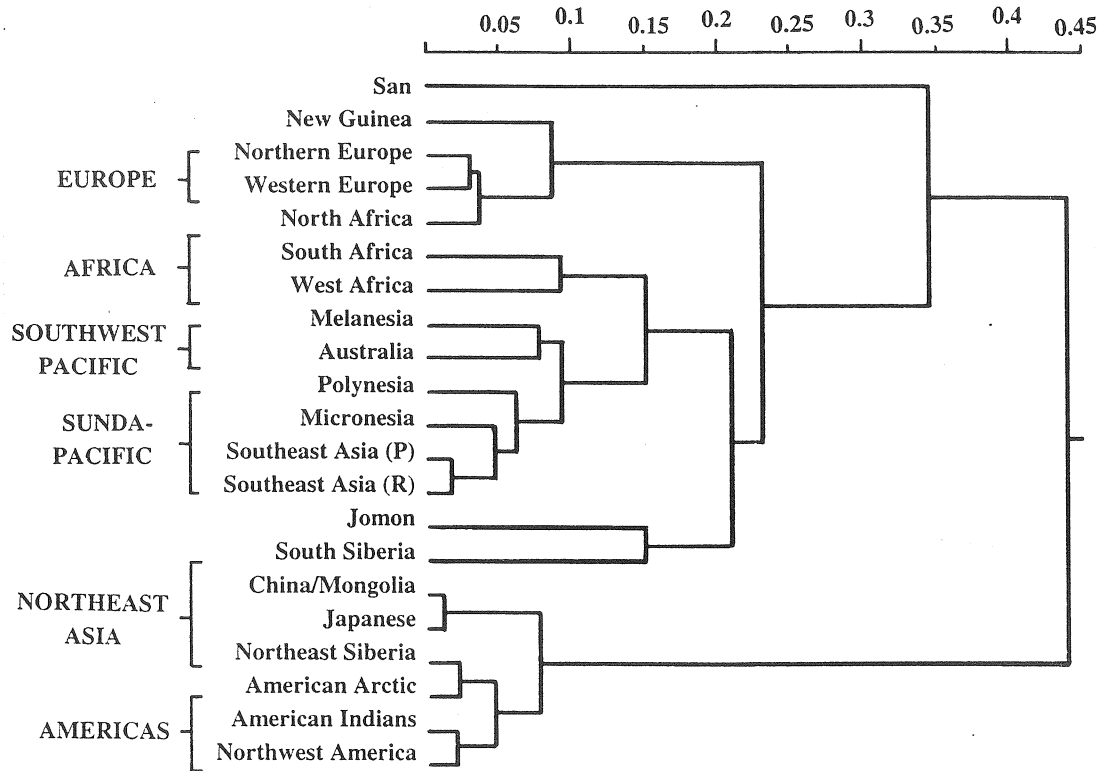


Figure 2. Seriated UPGMA tree of Nei distances based on 23 crown and root traits (goodness of fit 91.7%). (P) signifies prehistoric and (R) signifies recent.

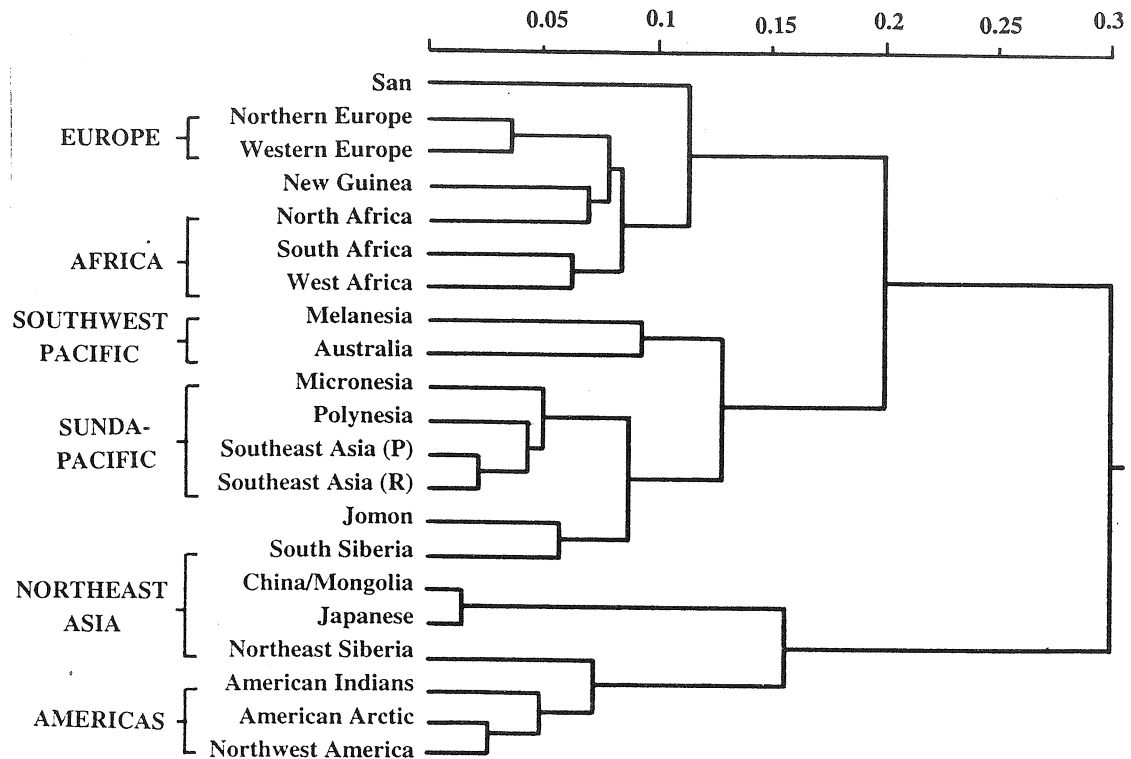


Figure 3. Seriated UPGMA tree of inter alia derivatives from Nei distances based on 23 crown and root traits (goodness of fit 91.6%).

Table 4. Seriated Nei distances between 21 regional samples (lower left half-matrix), adapted from Scott and Turner (1997:Table A.3), and *inter alia* derivatives (top right half-matrix)

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. San		.1355	.1094	.1174	.1293	.1192	.0872	.1916	.1723	.2479	.2337	.2812	.2643
2. New Guinea	.253		.0691	.0829	.0646	.0843	.0877	.1356	.1896	.2274	.2034	.2087	.2388
3. Northern Europe	.457	.071		.0332	.0839	.0918	.1088	.1404	.1757	.2201	.2141	.2428	.2365
4. Western Europe	.400	.110	.031		.0582	.1016	.1169	.1420	.1453	.2174	.2181	.2439	.2388
5. North Africa	.312	.081	.040	.046		.0663	.0933	.1001	.1563	.1943	.1837	.2132	.2099
6. South Africa	.174	.158	.205	.230	.094		.0581	.1007	.1364	.1851	.1723	.2056	.2034
7. West Africa	.220	.234	.364	.427	.262	.092		.1271	.1009	.2041	.1696	.2239	.2159
8. Melanesia	.299	.082	.117	.183	.105	.099	.104		.0923	.1243	.1003	.1313	.1346
9. Australia	.374	.257	.363	.451	.306	.191	.092	.078		.1161	.0929	.1439	.1382
10. Polynesia	.363	.175	.210	.231	.224	.248	.188	.076	.099		.0437	.0404	.0443
11. Micronesia	.297	.246	.253	.267	.184	.138	.133	.080	.096	.084		.0544	.0517
12. SE Asia (Prehist)	.302	.194	.194	.204	.146	.153	.164	.074	.101	.041	.033		.0215
13. SE Asia (Recent)	.301	.212	.225	.224	.164	.163	.193	.110	.123	.065	.062	.016	
14. Jomon	.387	.263	.276	.250	.261	.324	.346	.178	.230	.101	.167	.119	.172
15. South Siberia	.385	.214	.159	.127	.172	.310	.395	.217	.346	.102	.188	.087	.099
16. China/Mongolia	.529	.506	.480	.446	.409	.444	.461	.348	.302	.162	.196	.109	.077
17. Japan	.491	.514	.499	.451	.411	.416	.449	.335	.274	.156	.182	.106	.072
18. Northeast Siberia	.584	.731	.626	.623	.626	.603	.618	.470	.409	.230	.258	.181	.170
19. American Arctic	.692	.827	.727	.679	.727	.746	.741	.572	.491	.276	.352	.251	.240
20. American Indians	.716	.831	.685	.740	.685	.678	.648	.518	.441	.298	.278	.213	.226
21. NW America	.747	.876	.759	.751	.759	.795	.755	.598	.497	.292	.348	.243	.248

	14	15	16	17	18	19	20	21
1. San	.2139	.2493	.2672	.2799	.3105	.3342	.3114	.3374
2. New Guinea	.2168	.2541	.3168	.3015	.3572	.4021	.3827	.4150
3. North Europe	.1902	.1997	.2786	.2769	.3224	.3652	.3490	.3652
4. West Europe	.1859	.1923	.2747	.2766	.3126	.3517	.3288	.3663
5. North Africa	.1798	.1934	.2855	.2843	.3346	.3521	.3710	.4029
6. South Africa	.1817	.2129	.2942	.2983	.3501	.3914	.3705	.4094
7. West Africa	.1817	.2282	.2723	.2702	.3263	.3693	.3514	.3856
8. Melanesia	.1495	.1563	.2687	.2611	.3417	.3895	.3791	.4105
9. Australia	.1069	.1418	.2031	.1937	.2706	.3184	.3163	.3432
10. Polynesia	.0646	.0702	.1795	.1727	.2716	.3243	.2887	.3458
11. Micronesia	.0733	.0904	.1912	.1831	.2762	.3257	.3169	.3496
12. SE Asia (Prehistoric)	.0988	.0784	.1887	.1816	.2795	.3305	.3183	.3554
13. SE Asia (Recent)	.0855	.0748	.1725	.1709	.3076	.3128	.3013	.3385
14. Jomon		.0564	.1377	.1343	.2223	.2834	.2574	.3001
15. South Siberia	.141		.1406	.1352	.2230	.2794	.2616	.3033
16. China/Mongolia	.244	.133		.0153	.1014	.1637	.1503	.1881
17. Japan	.206	.153	.013		.1097	.1716	.1669	.1942
18. Northeast Siberia	.255	.209	.060	.051		.0691	.0574	.0889
19. American Arctic	.237	.237	.084	.072	.024		.0403	.0271
20. American Indians	.330	.253	.086	.105	.050	.079		.0461
21. Northwest America	.294	.234	.075	.087	.030	.030	.021	

To calculate the *inter alia* derivatives, I find the average of the Manhattan differences (absolute differences, sign of the difference ignored) between any two samples and every other sample. For instance, to find the *inter alia* derivative between San and New Guinea (see Table 4), we ignore the 0.253 distance between them, and instead find the average of $((0.457-0.071) + (0.400-0.110) + (0.312-0.081) \dots + (0.876-0.747))$, i.e. 0.1355. The rationale here is that if two samples are indeed similar biologically, they should be approximately the same distance from every other sample. Similarly, two biologically distant samples should have very different profiles of distances compared to the other analyzed samples, as recorded by a larger *inter alia* derivative. Inspection across the two half-matrices in Table 4 shows the high correlation between the original distances and the *inter alia* derivatives. One advantage of the *inter alia* derivatives is that they approximate Euclidean distances. That is, adding the distances between any X and Y, and between any Y and Z, produces a sum which equals or exceeds the distance between X and Z. Scott and Turner's original battery of Nei distances has many cases where this is not so (e.g., San-New Guinea 0.253 + New Guinea-North Europe 0.071 is much less than San-North Europe 0.457). Euclidean distances are suitable for any clustering algorithm, whereas non-Euclidean distances are inappropriate for some of these algorithms, such as minimum variance clustering (Orlóci 1978:211).

Figure 3 shows the result of a UPGMA tree, based on the *inter alia* derivatives in Table 4, seriated with reference to the original Nei distances. The seriated order hardly differs from Figure 2 and, consequently, the "goodness of fit" (91.6%) is virtually identical. Geographically, however, the clusters make more sense. Non-Sinodonts are split between those in the west (but including New Guinea) and those in the east. There is a distinct "Sundadont" cluster, here including Jomon and South Siberians, which then clusters with Australians and Melanesians. The San are construed as a marginal member of the African/European cluster, rather than appearing as the most isolated of all the non-Sinodont groups (as in Figure 2).

Only two geographically anomalous results persist. New Guinea remains linked with Europeans and North Africans, and the stability of this result (which recurs in Scott and Turner's other analyses) shows it is not an artifact of analysis. Presumably, the ancestral New Guinea populations had dental morphological profiles more like those recorded in Australia and Island Melanesia, before random genetic walk caused the convergence of the New Guinea and European/North African expressions (Scott

and Turner 1997:289-290). Second, the San remain farther removed from the other subsaharan African groups, South Africa and West Africa, than North Africans or, indeed, Europeans do. The San are the most idiosyncratic sample in the analysis, which presumably reflects an ancient divergence from the Bantu and other subsaharan Africans. Hence the San take an extreme position in the seriations, even though the greatest Nei distances are between New Guinea and Sinodont groups (Table 4).

The distinct status of the Sinodont cluster, combined with the cross-cluster proximity of other East Asian groups, suggests the following scenario. The ancestors of today's Sinodonts used to live in relative genetic isolation, which allowed the evolution of the Sinodont specializations. Later Sinodont populations then expanded geographically, not only into the Americas but also, to some degree, across the neighbouring parts of East Asia. Hence we have both patterns: (1) a relatively distinct Sinodont complex, but (2) a cline towards and into the non-Sinodont dental morphological pattern at the East Asian boundaries of Sinodontology. This cline would presumably reflect ancient clines as well as more recent flow of genes and people from densely populated Northeast Asia into adjacent regions. Further discussion of this scenario will follow in the next analysis.

In summary, UPGMA clustering combines with seriation to identify three main groups. We have a stable Sinodont cluster, which Scott and Turner also call Sino-America (and to which they problematically assign Jomon and South Siberia). We have a Sunda-Pacific cluster (Southeast Asians, Polynesians and Micronesians) which is close to Jomon and South Siberia on the one hand, and to Australians and Island Melanesians on the other hand. We also have a western grouping (which constitutes its own cluster in Figure 3) where the dental morphological affinities of the New Guinea sample clearly lie. Finally, the extremely close similarity between recent and prehistoric Southeast Asians is to be expected, as the prehistoric Southeast Asian sample comprises mainly Neolithic and Metal Age teeth.

GUA CHA COMPARED ON A GLOBAL SCALE

Scott and Turner (1997:238-42) use a Middle East example, with at least six observations for each dental trait, to show how to assign a small archaeological sample of teeth to a major dental complex. Table 5 shows the results of applying this methodology to Gua Cha. Jomon/South Siberia alone shows more agreements than disagreements with the Gua Cha Hoabinhian teeth. The Neolithic teeth, on the other hand, appear African, with an Australian or Melanesian affinity as a second possi-

bility. This latter result reflects the low shovelling incidence on the Gua Cha Neolithic teeth, and the strong expression of cusps, including Carabelli's trait, on the upper molars. However, the calculation of MMD distances, appropriately modified for small samples (Johnson and Lovell 1994) somewhat qualifies these observations. The Jomon are very close to Gua Cha Hoabinhian teeth, while Early Southeast Asia and Micronesia are also close; South Siberia is far away (Table 6). As regards the Neolithic teeth, Australian Aborigines are very close, while Polynesia, West Africa and Melanesia are all tolerably close.

The most straightforward interpretation of these results is that a pre-Neolithic, Jomon-like dental morphology gave way to a more "Australo-Melanesian" or even African dental morphology during the Neolithic. This interpretation should possibly not be rejected out of hand. Some differences in the frequencies of dental morphological variants should be expected as the natural outcome of ongoing biological evolution, especially if small population sizes had enhanced the scope for genetic drift. Disregarding the potential role for biological evolution, Bellwood (1993) proposed that the Gua Cha Hoabinhians represent the hunter-gatherer population ancestral to the Semang, while the Gua Cha Neolithic population belongs to the ancestry of the Senoi. This proposal would be confirmed if future studies reveal that the Semang have a Jomon-like dental morphology, and the Senoi teeth have a more Australo-Melanesian or African pattern. Nonetheless, the present results would certainly rebut Bellwood's (1993:46) specific suggestion that the Senoi owe a considerable part of their ancestry to Mongoloids who migrated from Thailand to West Malaysia during the Neolithic. Compared to the Hoabinhians, the Gua Cha Neolithic teeth show a distinct shift towards a less "Mongoloid" dental morphology.

However, there are several grounds for pooling the Gua Cha Hoabinhian and Neolithic series into a larger sample. Statistically, the individual trait incidences (Appendix 1) are not significantly different. The MMD distance between the samples for the six traits listed for them both in Table 5 is 0.001, which is very small. Further, as reviewed by Bellwood (1997:85), previous studies have not recorded any notable differences between the Gua Cha Hoabinhian and Neolithic human remains. But if Gua Cha is treated as a pooled sample, the number of similarities approximately matches the number of dissimilarities only in the comparisons involving Australia/Melanesia, Africa, and Jomon/Siberia (Table 5). Further, the MMD distances would find plausible comparisons only with Australian Aborigines and Polynesians, all

other possibilities being remote (Table 6).

In one sense, then, pooling the Hoabinhian and Neolithic series merely compounds confusion. If both were samples of the same population, we would normally expect pooling to tend to even out irregularities. But in this case, the pooled sample would be more irregular than its components which had convincingly appeared, respectively, Jomon-like and Australian-like. Hence the available evidence does suggest that the Hoabinhian and Neolithic teeth represent populations which are different in their dental morphology. What is abundantly clear, though, is that the Neolithic teeth display the opposite of the more Mongoloid pattern that Bellwood (1993) had expected.

In another sense, if we focus on the MMD values, all the comparisons produce a similar result. All cases of similar comparative populations fall within the segment of the seriated dendrograms (Figures 2 and 3) between Australian Aborigines and the Jomon. The pooled Gua Cha sample would map onto the Australia/Polynesia segment of the dendrograms. Although Gua Cha fails to affine with Sundadonts in any of the comparisons, it consistently resembles populations which broadly associate with the Sundadonts. This would suggest that the Gua Cha Hoabinhian and Neolithic series represent micro-population variation within a broader population complex which, while variable, is subtly distinct from Turner's Sundadont complex. Hence, the resolution to our uncertainties may lie in pooling the Gua Cha teeth into a still larger sample which would be likely to cover the range of micro-populations from which the Hoabinhian and Neolithic series were probably drawn.

EARLY MALAY ARCHIPELAGO TEETH ON THE OLD WORLD SCALE

Our second hierarchical clustering analysis involves MMD distances, based on 28 dental traits, between the Old World samples in Turner's (1992:Figure 1) minimum-variance dendrogram. Turner kindly forwarded these distances to me in 1993. MMD and Nei distances are calculated differently but, as Scott and Turner (1997:257) point out, the different formulae for estimating biological distances tend to produce highly correlated results. This large array of Old World samples presents several advantages. It includes several "mystery groups" such as the Ainu and Andaman Islanders. It allows us to investigate the degree of heterogeneity within Scott and Turner's wide-ranging geographical samples, such as Polynesia and Island Melanesia, which involved aggregations of smaller samples of more limited provenance. Finally, the matrix of distances posted to me by Turner

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Table 5. Trait by trait worldwide comparisons of the Gua Cha teeth (minimum of 6 observations in either series)

HOABINHIANS	Sunda-Pacific	Jomon/South Siberia	Australia/Melanesia	New Guinea	Northeast Asia/America	Africa	Europe
Trait							
Incisor shovelling (30%)	+	+	+	—	—	—	—
I double-shovelling (0%)	—	+	+	+	—	+	—
I ₂ interruption grooves (57%)	—	+	—	—	+	—	—
C mesial ridge (0%)	—	+	+	+	+	—	—
Premolar odontomes (0%)	+	+	—	+	+	+	+
3-cusped M ₂ (0%)	—	—	—	—	—	+	—
Carabelli's cusp M ₁ (0%)	—	±	—	—	±	—	—
First molar							
enamel extensions (13%)	+	+	—	—	—	—	—
2-rooted lower canines (0%)	+	+	+	+	+	+	—
Tomes' root (0%)	—	—	—	—	—	+	—
3-rooted lower M ₁ (50%)	—	—	—	—	±	—	—
1-rooted lower M ₂ (0%)	—	—	—	—	—	±	—
NEOLITHIC	Sunda-Pacific	Jomon/South Siberia	Australia/Melanesia	New Guinea	Northeast Asia/America	Africa	Europe
Trait							
Incisor shovelling (10%)	—	—	+	—	—	+	—
I double-shovelling (0%)	—	+	+	+	—	+	—
Premolar odontomes (0%)	+	+	—	+	+	+	+
3-cusped M ₂ (0%)	—	—	—	—	—	+	—
5-cusped M ₁ (100%)	—	—	±	—	—	±	—
Carabelli's cusp M ₁ (33%)	+	—	—	—	—	+	+
First molar							
enamel extensions (18%)	+	+	—	—	—	—	—
4-cusped lower M ₁ (0%)	+	+	+	+	+	+	—
Y pattern lower M ₂ (0%)	—	—	—	—	±	—	—
Cusp 6 lower M ₁ (67%)	—	—	+	—	—	—	—
POOLED	Sunda-Pacific	Jomon/South Siberia	Australia/Melanesia	New Guinea	Northeast Asia/America	Africa	Europe
Trait							
Incisor shovelling (20%)	+	+	+	—	—	—	—
I double-shovelling (0%)	—	+	+	+	—	+	—
I ₂ interruption grooves (40%)	+	—	—	—	+	—	+
C mesial ridge (0%)	—	+	+	+	+	—	—
Premolar odontomes (0%)	+	+	—	+	+	+	+
3-cusped M ₂ (0%)	—	—	—	—	—	+	—
Carabelli's cusp M ₁ (20%)	+	+	+	+	—	+	+
5-cusped M ₁ (100%)	—	—	±	—	—	±	—
First molar							
enamel extensions (16%)	+	+	—	—	—	—	—
4-cusped lower M ₁ (0%)	+	+	+	+	+	+	—
Y pattern lower M ₂ (0%)	—	—	—	—	±	—	—
Cusp 6 lower M ₁ (89%)	—	—	+	—	—	—	—
2-rooted lower canines (0%)	+	+	+	+	+	+	—
Tomes' root (0%)	—	—	—	—	—	+	—
3-rooted lower M ₁ (43%)	—	—	—	—	±	—	—
1-rooted lower M ₂ (0%)	—	—	±	—	—	±	—

Notes to Table 5:

+ signifies the Gua Cha incidence falls within the range of ± 2 standard errors of the comparative groups.

 \pm signifies the Gua Cha incidence is extreme, but it is approached by the comparative groups indicated.

— represents other instances where the Gua Cha incidence falls outside the ± 2 standard errors of the comparative groups.

See Figs 2 and 3 for the major dental complexes (e.g. Sunda-Pacific) as recognized for the purposes of the current exercise.

Table 6. Mean Measure of Divergence (MMD) distances between Gua Cha and comparative dental samples (based on the traits listed in Table 5)

Comparative dental sample	Gua Cha Hoabinhian	Gua Cha Neolithic	Gua Cha pooled
Australian Aborigines	0.123	0.032	0.148
Polynesia	0.114	0.126	0.173
Melanesia	0.165	0.170	0.227
Early Southeast Asia	0.095	0.258	0.253
Jomon	0.040	0.358	0.277
Micronesia	0.099	0.284	0.282
West Africa	0.316	0.133	0.283
Recent Southeast Asia	0.122	0.296	0.292
New Guinea	0.297	0.400	0.388
South Siberia	0.228	0.409	0.422
China-Mongolia	0.229	0.561	0.429
North Africa	0.171	0.503	0.465

restricted his Early Malay Archipelago sample to Gua Cha, Guar Kepah, Sampung and Flores. As the Flores component is small, Early Malay Archipelago in this analysis essentially samples Holocene pre-Neolithic and Neolithic teeth from the western Indo-Malaysian Archipelago (Java and Malaya). Finally, the matrix that Turner sent to me separately tabulated the Early Metal Phase Leang Codong sample (which is added here to the 46 groups in Turner's 1992 dendrogram).

The MMD distances are quite non-Euclidean, involving numerous cases where the sum of any X-Y and Y-Z distances is far smaller than the corresponding X-Z distances. In many cases these X-Y or Y-Z distances even register as zero, even though a distance of zero should signify coincidence (e.g. Tasmania-Solomons 0.0, Solomons-Holland 0.327, Tasmania-Holland 0.584). All this suggests that the *inter alia* derivative between any pair of samples may be a more reliable indicator of their actual biological relationship, within the context of the sampled populations, than the original MMD distance. Appendix 2 presents the *inter alia* derivatives between the samples (nonetheless the seriated order, and the calculated goodness of fit, are still based on Turner's MMD distances). The UPGMA tree of the original MMD distances (Figure 4) has a slightly better goodness of fit,

74.4%, than the UPGMA tree derived from the *inter alia* derivatives has (73.2%, Figure 5). The following discussion covers both trees because the similarities are pronounced and the differences are instructive. Turner (1992:146, 149) makes many of the same points in his discussion of his minimum-variance dendrogram, but without sharing my focus on the status of the Early Malay Archipelago sample.

The major difference between my two dendrograms involves the suggested relationship of the Tasmanians. In Figure 4, Tasmanians and Solomon Islanders cluster and are placed at the Northeast Asian pole, far away from any other southwest Pacific sample. West Africa loosely clusters with North African, Indian and southwest Pacific samples. In Figure 5, Solomon Islanders effectively swap places with West Africans. West Africa clusters loosely with Tasmanians, while Solomon Islanders lie near the circum-Indian Ocean samples. The West Africa-Tasmania link in Figure 5 is an artifact of analysis, which results from the great "*inter alia*" dissimilarity of the West African and Tasmanian samples from any other samples in the analysis (Appendix 2). Figure 5 does, however, show that the apparent Tasmanian-Solomon Islander link in Figure 4 is not reliable either. Basically, the Tasmanians' dental morphology is aberrant, pre-

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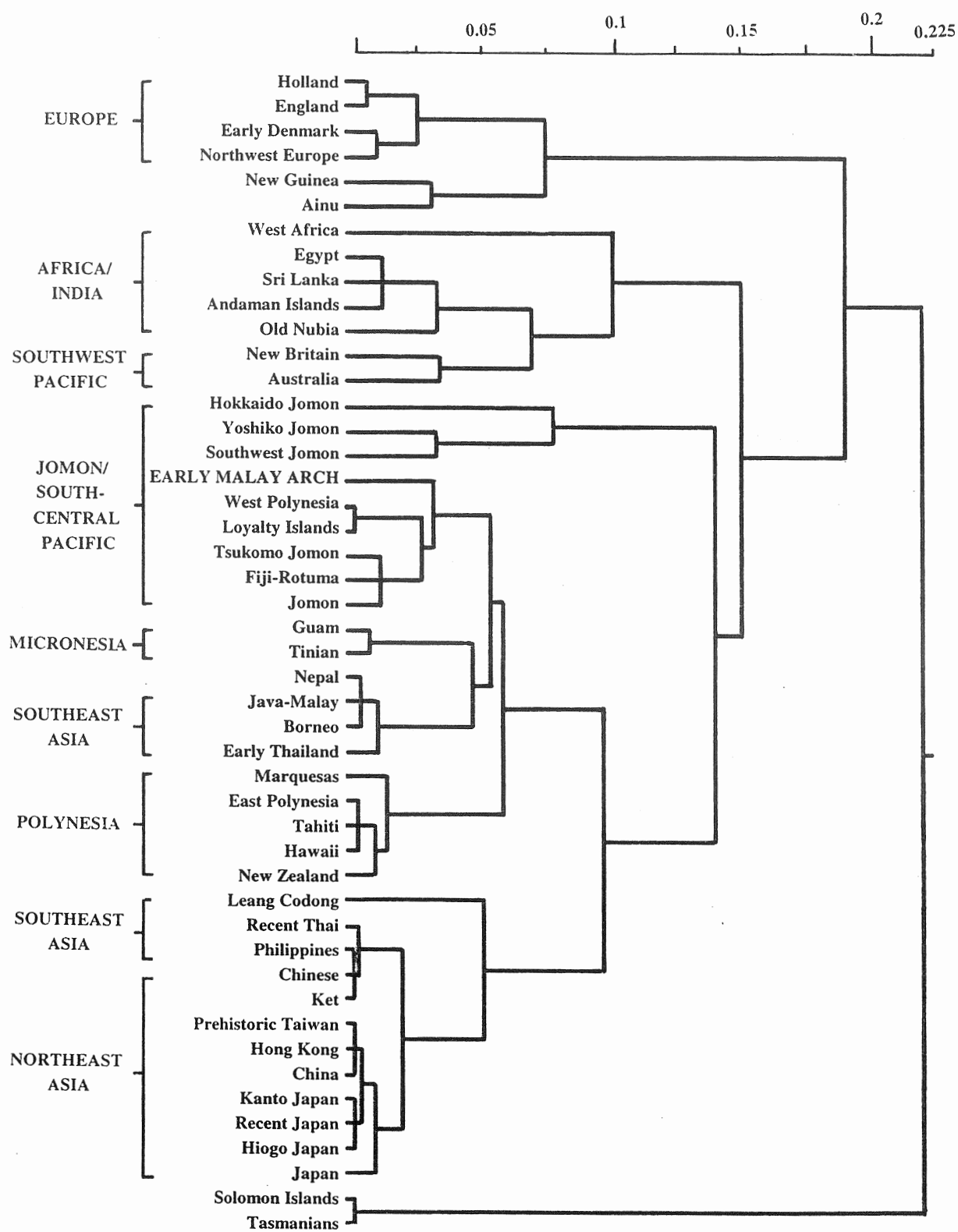


Figure 4. Seriated UPGMA tree of MMD distances based on 28 crown and root traits (goodness of fit 74.4%)

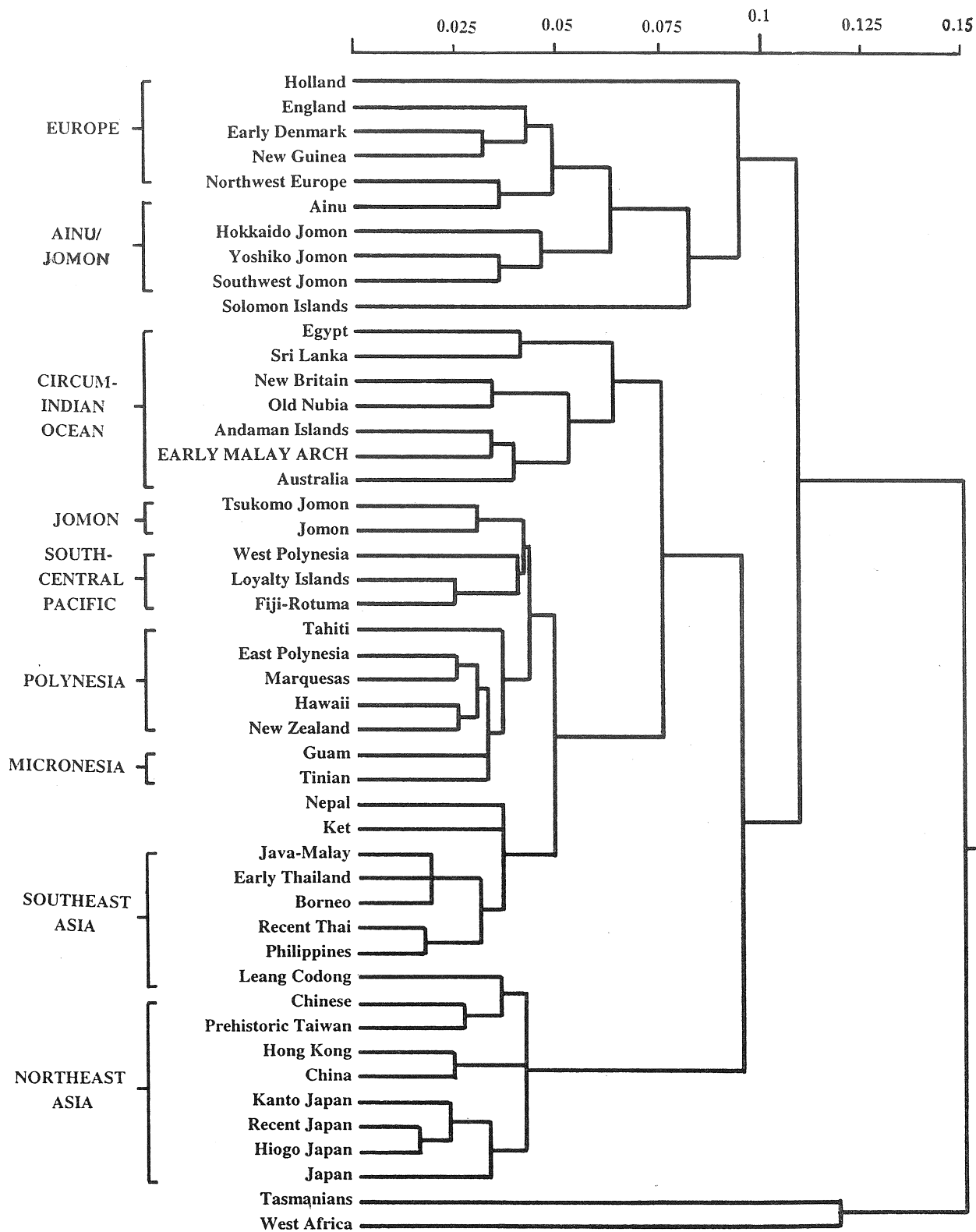


Figure 5. Seriated UPGMA tree of inter alia derivatives from MMD distances based on 28 crown and root traits (goodness of fit 73.2%)

sumably the result of random genetic walk during the Tasmanians' millennia of isolation during the Holocene. This proposal is analogous to the explanation for the non-Pacific profile of the New Guinea dental morphology except that the latter, by chance, has apparently converged on the European condition.

Whether Tasmanians are considered or not, the southwest Pacific samples show a diversity which contrasts with the tendency of the Northeast Asian, Southeast Asian, Micronesian and Polynesian samples to form their own clusters or, at least, to seriate close together (Figures 4 and 5). Nonetheless, most of the southwest Pacific samples can be seen to link up with Indian Ocean, African or European samples, while seriation positions the circum-Indian Ocean samples (Nubia, Egypt, Sri Lanka, Andaman Islands, Australia) and the European samples towards the same pole. This suggests that the peoples of Africa, Europe, South Asia and the southwest Pacific have derived from an ancient, ancestral population complex with morphologically simple teeth which lacked the specializations found among the various present-day descendants. The Ainu of Japan would have to be included here, as arguably would the prehistoric Jomon, whose samples either seriate near the Ainu, or fall between Australian Aborigines and Sundadont samples (Figures 4 and 5).

Scott and Turner (1997:304-7) use their similar findings to propose an ancestral "proto-Sundadont" complex which they associate with the rise of anatomically modern *Homo sapiens* in Late Pleistocene Southeast Asia. Further debate on this hypothesis lies beyond the scope of my article, except to say that the available evidence would be equally supportive of an African (Stringer 1993, Irish 1998) or a South Asian homeland for anatomically modern people. What interests us here is that Turner's Early Malay Archipelago sample would be considered a representative descendant of "proto-Sundadonty" in these analyses. It consistently falls within the Jomon range of variation. The specific similarities previously noted for the various Gua Cha samples are all brought together as the general affinity of Early Malay Archipelago teeth. Turner (1990) on the contrary failed to recognize the distinction between Early Malay Archipelago and recent "Malay" teeth, either because of the small number of traits he considered, or because of the lack of rigorous statistical analysis.

If we exclude the problematical Tasmanians, Solomon Islanders and West Africans, then both Figures 4 and 5 produce similar seriations, with Europeans at one pole and Japanese at the other. (By analogy with Figures 2 and 3, New World populations would lie beyond the

Japanese.) Both dendrograms break down the apparent distinctiveness of the Sinodonts noted previously in this paper. They firmly place Turner's prehistoric Taiwan (4000-1500 BP), and Early Metal Phase Sulawesi (Leang Codong) samples, in the Sinodont cluster. Further, the recent Thai and Philippine samples also cluster with the Sinodonts, or seriate next to them. Turner (1990:315) had also noted the Sinodont tendencies of Leang Codong and prehistoric Taiwan teeth, and the resultant evidence for a Sinodont to Sundadont cline in East Asia. Hence in East Asia we are dealing more with a gradual cline in dental morphology than a sharp distinction between Sinodonts and Sundadonts. But to what degree might this cline reflect Neolithic "Mongoloid" migrations, and absorption of the hunter-gatherer indigenes, as opposed to a more ancient morphological cline?

In Figure 5, prehistoric Taiwan and Leang Codong stand to one side of the recent Southeast Asian, Polynesian, and Micronesian samples, while the Jomon-like Early Malay Archipelago sample stands to the other side. One interpretation of this pattern would be that Sundadonty has resulted from the prehistoric admixture of indigenous Island Southeast Asians with immigrants, of Northeast Asian descent, who moved from Taiwan through Sulawesi into the rest of Island Southeast Asia. This interpretation would support the models of Jacob (1967) and especially Bellwood (e.g. 1997) for the derivation of modern Island Southeast Asian peoples. Figure 4, however, suggests a geographical explanation; specifically, a cline in Island Southeast Asia from less "Mongoloid" teeth in the south and the west, to more "Mongoloid" teeth in the northeast. Such a cline might have been established as early as the Late Pleistocene. The island chain between Sulawesi and Taiwan has not yet produced the substantial Late Pleistocene and early Holocene samples that could help determine when Sinodont tendencies first appeared in these islands. The renowned Tabon jaw has a three-rooted first lower molar which demonstrates the pre-Neolithic establishment of this chiefly "Mongoloid" trait (Bulbeck 1981:99-100; Turner 1992). However, the Gua Cha Hoabinhian sample also exhibits a surprisingly high rate of three-rooted lower first molars (Table 5) without displaying a Sundadont or Sinodont profile overall (Table 6).

In summary, Figures 4 and 5 show that the "Early Malay Archipelago" sample used in Turner (1987) combined a Sinodont-like sample (Leang Codong) and a sample with broad circum-Indian Ocean affinities (Gua Cha, Guar Kepah, Flores, Sampung). Not surprisingly, the combination resulted in a sample with the sorts of intermediate trait frequencies found among Turner's re-

cent Island Southeast Asian samples. In his 1990 paper, Turner separated Leang Codong from his Early Malay Archipelago sample but could not recognize the non-Sundadont status of the latter. Finally, Figures 4 and 5 are consistent with Mongoloid immigration scenarios such as those of Jacob, Brace and Bellwood. Nonetheless, for these scenarios to be confirmed, we would require demonstration of a transition to Sundadonty moving between the pre-Neolithic and Neolithic dental samples within the same location. The single test case to date, Gua Cha, produces no evidence for any such transition, and while there are solid grounds for expecting Gua Cha to be exceptional, a positive demonstration is needed to prove the rule.

While the evidence for a Neolithic "Mongoloid" immigration into Southeast Asia is inconclusive, based on Figures 4 and 5, there is strong evidence for a post-Neolithic input from Northeast Asia (see also Turner 1987:319; Turner 1990:315; Scott and Turner 1997:297). Turner's recent Thai sample is closer to Northeast Asians than is his Early Thailand sample which comprises teeth from Neolithic, Bronze and Iron Age sites (Scott and Turner 1997:320). Turner's recent Java-Malay sample also far more closely approaches Sinodonts than does his Early Malay Archipelago sample and, given the substantially Neolithic composition of the latter sample, this may be informative mainly of post-Neolithic trends. The post-Neolithic infiltration of Southeast Asia by Chinese and other Northeast Asians is a process that has clearly been underway since the dawn of Southeast Asian history (e.g. Fitzgerald 1972; Wheatley 1983). The operation of this process during historical times is no guarantee of its prehistoric existence and, indeed, merely increases the peril that historical developments will be confused for prehistoric trends.

IMPLICATIONS FOR WEST MALAYSIA

The Hoabinhian and Neolithic dental samples at Gua Cha cannot be clearly distinguished from each other in any two-way comparison, but their preferred affinities are with quite distinct "para-Sundadont" groups. Local dental morphological evolution would possibly, but not necessarily, provide a sufficient explanation. Hence, at the Neolithic junction, use of the rock shelter might have been taken over by a group distinct from the Hoabinhians at the level of micro-differentiation. Any such Neolithic group, however, could not be characterized as "southern Mongoloid" by the wildest stretch of the imagination. This result might suggest that the Neolithic in West Malaysia witnessed the expansion of one local population

(or perhaps more) at the expense of other, skeletally similar local populations.

In support of this hypothesis, the pooled Early Malay Archipelago sample (in Figure 5) clusters most closely with Andaman Islanders, a group of "Negritos" living close to the Malay Peninsula. This result parallels the previous demonstration of a craniometric similarity between Andamanese, and West Malaysia's "Negrito" Semang and non-Negrito Senoi (Bulbeck 1996). We are clearly not dealing with the delineation of a distinct Negrito group, as shown by the incorporation of South Indians (Sri Lanka in Figure 5, Tamils in Bulbeck 1996) and other non-Negrito groups in the selfsame clusters. Moreover, the Gua Cha Hoabinhian teeth specifically resemble Jomon teeth, and the Early Malay Archipelago teeth consistently seriate with the Jomon samples in Figures 4 and 5. The Andamanese and Malay Peninsula Aborigines do seem to have stemmed from an earlier tropical Old World population, which was neither specifically Negritoid nor "Australo-Melanesian", and which had extended as far as prehistoric Japan. These observations are compatible with my earlier conclusion (Bulbeck 1996) that the Gua Cha Neolithic population represents the local ancestry of the Senoi, apart from a component of Mongoloid admixture which would postdate Neolithic times.

This identification between Senoi ancestry and the Gua Cha Neolithic endorsed a view previously expressed by Benjamin (1987:118) and Bellwood (1993), but it may no longer be tenable. Benjamin (1996:3-4; 1997:101) now accepts a homeland for the languages spoken by the Senoi in the lowlands to the west of the main range, followed by expansion into the main range and, only much later, a movement into the western lowlands where Gua Cha is located (see Figure 1). Similarly, Bellwood (1997:85, 265) is very circumspect about upholding Gua Cha as an example of the association he would normally expect between the Neolithic in West Malaysia and the origins of the Senoi. These perspectives increase the likelihood that the Gua Cha Neolithic population lies close to the direct ancestry of the Semang.

In sum, the advent of the Neolithic in the vicinity of Gua Cha (by whatever steps that involved) may have been entirely independent of the origins and early expansion of the ancestors of the Senoi in the western belt of West Malaysia. The observed craniometric similarities between the Semang and the Senoi could at least partly reflect parallel evolution, in which one component among the Senoi may have involved some "Mongoloid" admixture from farther north. Guar Kepah, on the west coast, complicates the picture as it contains cord-marked

potsherds (Bellwood 1997) but no definite cases of primary extended burials (Jacob 1967). If Guar Kepah could be taken as evidence of the skeletal phenotype on West Malaysia's west coast on the eve of the Neolithic, we would be dealing with a quite large-toothed population (Jacob 1967) with longer crania and more massive mandibles than those from Gua Cha (Bulbeck 1996). Certainly the scenario of substantial immigration into western West Malaysia, associated with establishing the Ban Kao culture there and the origins of the Senoi, cannot be rejected on the basis of what may possibly be irrelevant comparisons from Gua Cha.

Further review of the available data shall be left to later papers. West Malaysia clearly has great potential for documenting dental morphological change at the local level during the Holocene. It includes numerous Hoabinhian, Neolithic and later sites (see Figure 1) with samples of human teeth which are the subject of my ongoing research. I have also obtained dental casts from Semang, Senoi and "Aboriginal Malay" groups which will, for the first time, allow an assessment of their dental morphological affinities compared to surrounding populations (Bulbeck and Kadir 1999). The above information should enlighten us on whether the Malay Peninsula Hoabinhians, and later groups, can be considered "proto-Sundadont", and how dental morphology might relate to other indicators of population affinity.

CONCLUSION

Gua Cha is the only site in the Indo-Malaysian Archipelago which has sufficiently distinct and substantial pre-Neolithic and Neolithic samples to enable a test between the local evolutionary and Mongoloid immigration theories on the biological origins of the "southern Mongoloids". Turner's local evolutionary theory would expect both samples to appear Sundadont, while the immigration scenarios proposed by Brace (1978) and Bellwood (1993) would expect the Neolithic sample alone to appear Sundadont. Actually, neither sample can be characterized as Sundadont. Hence the advent of the Neolithic in the vicinity of Gua Cha evidently involved continuity of the same population as the Hoabinhian forebears or, at most, the immigration of a phenotypically similar population. However, Gua Cha tells us nothing about the likelihood of pre-Neolithic to Neolithic continuity of the gene pool in other parts of Southeast Asia where Sundadonty prevailed by late prehistoric times.

It remains entirely possible that the ancestry of the Senoi is linked to substantial immigration from farther north during the Neolithic. This scenario is enabled by the indications that the Senoi pushed into the vicinity of

Gua Cha, presumably Semang lands at the time, only in post-Neolithic times. As a hypothesis it can be most directly tested with reference to the human remains in the western belt of West Malaysia. These remains might accord with the pattern at Gua Cha of no or negligible "Mongoloid" immigration until post-Neolithic times, or they might identify one area in West Malaysia where Neolithic immigration had probably occurred.

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NOTES

1. The following investigated cases did not yield statistically significant differences. M₁ and M₂ hypocone; grades 4-5 on all 8 Hoabinhian cases, but grade 3 on 7 Neolithic cases compared to grades 4-5 in 12 other cases; Fisher Exact Test, $p = 0.056$. M₁ enamel extension, grade 0 in 15 Hoabinhian cases and 1-2 in the 17 other Hoabinhian cases, grade 0 in 3 Neolithic cases compared to grades 1-2 in 11 Neolithic cases. Chi-square test can be applied in this case as the expected frequency exceeds 5 in every cell in the resulting contingency table. Chi-square = 2.63, 1 degree of freedom, $p > 0.05$.

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APPENDIX 1. DENTAL MORPHOLOGICAL OBSERVATIONS AT GUA CHA

Anterior teeth (percentage incidences)

Trait and Expression	Hoabinhians: Tooth and frequency			Neolithic: Tooth and frequency		
Shovelling	I ₁ (n=5)	I ₂ (n=5)	lower C (n=9)	I ₁ (n=6)	I ₂ (n=4)	lower C (n=8)
0 None	20.0	40.0	100.0	33.3	25.0	75.0
1-2 Faint/Trace	40.0	40.0	0.0	66.7	50.0	25.0
3-4 Semi-shovel	40.0	20.0	0.0	0.0	25.0	0.0
5-6 Full shovel	0.0	0.0	0.0	0.0	0.0	0.0
Tuberculum Dentale	I ₁ (n=7)	I ₂ (n=7)	C (n=8)	I ₁ (n=5)	I ₂ (n=4)	C (n=4)
0 None (smooth)	28.6	14.3	25.0	0.0	0.0	0.0
1 Weak ridging	28.6	42.9	25.0	40.0	100.0	75.0
2	28.6	42.9	37.5	20.0	0.0	25.0
3	14.3	0.0	12.5	20.0	0.0	0.0
4-5	0.0	0.0	0.0	20.0	0.0	0.0
Incisor Interruption Grooves	I ₁ (n=6)	I ₂ (n=7)		I ₁ (n=5)	I ₂ (n=3)	
0 None	50.0	42.9		20.0	100.0	
1 Mesial lingual area	0.0	0.0		20.0	0.0	
2 Distal lingual border	0.0	0.0		0.0	0.0	
3 Medial lingual area	16.7	57.1		60.0	0.0	
4 Mesial & distal borders	33.3	0.0		0.0	0.0	
Canine Distal Accessory Ridge	C (n=5)	lower C (n=5)		C (n=2)	lower C (n=3)	
0 None	40.0	0.0		50.0	0.0	
1 Trace	60.0	80.0		50.0	66.7	
2 Weak	0.0	20.0		0.0	33.3	
3-5 Moderate to strong	0.0	0.0		0.0	0.0	

Upper Premolars (percentage incidences)

Trait and Expression	Hoabinhians: Tooth and frequency		Neolithic: Tooth and frequency	
Accessory Ridges	P ₁ (n=1)	P ₂ (n=2)	P ₁ (n=5)	P ₂ (n=3)
0 Absent	100.0	50.0	100.0	100.0
1 Present	0.0	50.0	0.0	0.0
Accessory Marginal Tubercles	P ₁ (n=1)	P ₂ (n=2)	P ₁ (n=6)	P ₂ (n=5)
0 Absent	0.0	50.0	66.7	80.0
1 Present	100.0	50.0	33.3	20.0
Number of Roots	P ₁ (n=5)	P ₂ (n=2)	P ₁ (n=2)	P ₂ (n=2)
1 Single	60.0	50.0	0.0	0.0
2 Double	40.0	50.0	100.0	100.0

Lower Premolars (percentage incidences)

Trait and Expression	Hoabinhians: Tooth and frequency		Neolithic: Tooth and frequency	
Lower Premolar Accessory Ridges	P1 (n=8)	P2 (n=8)	P1 (n=6)	P2 (n=7)
0 Absent	75.0	75.0	66.7	85.7
1 Present	25.0	25.0	33.3	14.3
Lower Premolar Lingual Cusp Number	P1 (n=9)	P2 (n=7)	P1 (n=7)	P2 (n=7)
1	66.7	14.3	28.6	28.6
2	33.3	71.4	71.4	71.4
3	0.0	14.3	0.0	0.0
4-9	0.0	0.0	0.0	0.0

Upper Molars (percentage incidences)

Trait and Expression	Hoabinhians: Tooth and frequency			Neolithic: Tooth and frequency		
Metacone size	M1 (n=4)	M2 (n=4)	M3 (n=8)	M1 (n=11)	M2 (n=8)	M3 (n=5)
1-2 Very small	0.0	0.0	0.0	0.0	0.0	0.0
3 Small	0.0	0.0	25.0	36.4	37.5	40.0
4 Large	75.0	0.0	50.0	36.4	12.5	20.0
5 Very large	25.0	100.0	25.0	27.3	50.0	40.0
Hypocone size	M1 (n=3)	M2 (n=6)	M3 (n=10)	M1 (n=11)	M2 (n=8)	M3 (n=4)
0-1 Absent to faint	0.0	0.0	0.0	0.0	0.0	0.0
2 Very small	0.0	33.3	10.0	0.0	25.0	75.0
3 Small	0.0	0.0	40.0	0.0	37.5	25.0
4 Large	100.0	33.3	40.0	63.6	12.5	0.0
5 Very large	0.0	33.3	10.0	36.4	25.0	0.0
Metaconule (Cusp 5)	M1 (n=2)	M2 (n=2)	M3 (n=4)	M1 (n=7)	M2 (n=5)	M3 (n=2)
0 Absent	0.0	50.0	25.0	0.0	60.0	0.0
1 Faint	0.0	0.0	0.0	0.0	20.0	0.0
2 Trace	100.0	50.0	0.0	100.0	20.0	0.0
3 Small cuspule	0.0	0.0	25.0	0.0	0.0	100.0
4 Small cusp	0.0	0.0	50.0	0.0	0.0	0.0
5 Medium-size cusp	0.0	0.0	0.0	0.0	0.0	0.0
Carabelli's Cusp	M1 (n=8)	M2 (n=9)	M3 (n=8)	M1 (n=12)	M2 (n=9)	M3 (n=5)
0 Smooth	25.0	44.4	62.5	33.3	66.7	20.0
1 Groove	50.0	44.4	25.0	16.7	11.1	0.0
2-4 Pit to Y depression	25.0	11.1	0.0	16.7	11.1	60.0
5 Small cusp	0.0	0.0	12.5	8.3	11.1	20.0
6 Medium cusp	0.0	0.0	0.0	25.0	0.0	0.0
7 Large cusp	0.0	0.0	0.0	0.0	0.0	0.0
Upper Molar Enamel Extension	M1 (n=9)	M2 (n=11)	M3 (n=12)	M1 (n=7)	M2 (n=5)	M3 (n=2)
0 None	33.3	45.5	58.3	14.3	40.0	0.0
1 Slight	66.7	45.5	41.7	71.4	60.0	100.0
2 Moderate	0.0	9.1	0.0	14.3	0.0	0.0
3 Pronounced	0.0	0.0	0.0	0.0	0.0	0.0

Lower Molars (percentage incidences)

Trait and Expression		Hoabinhians: Tooth and frequency			Neolithic: Tooth and frequency		
Lower Molar Enamel Extension		M1 (n=6)	M2 (n=13)	M3 (n=14)	M1 (n=10)	M2 (n=10)	M3 (n=6)
0	None	16.7	0.0	21.4	20.0	40.0	16.7
1	Slight	50.0	69.2	57.1	60.0	50.0	66.7
2	Moderate	33.3	30.8	21.4	20.0	10.0	16.7
3	Pronounced	0.0	0.0	0.0	0.0	0.0	0.0
Lower Molar Groove Pattern		M1 (n=3)	M2 (n=5)	M3 (n=9)	M1 (n=9)	M2 (n=6)	M3 (n=7)
Y	Cusps 2 & 3 in contact	100.0	0.0	11.1	77.7	0.0	0.0
+	Cusps 1 to 4 in contact	0.0	40.0	22.2	0.0	50.0	0.0
X	Cusps 1 & 4 in contact	0.0	60.0	66.7	22.2	50.0	100.0
Lower Molar Cusp 5		M1 (n=3)	M2 (n=2)	M3 (n=4)	M1 (n=7)	M2 (n=3)	M3 (n=5)
0	Absent	0.0	100.0	50.0	0.0	0.0	20.0
1	Very small	0.0	0.0	0.0	0.0	0.0	0.0
2	Small	0.0	0.0	0.0	28.6	0.0	0.0
3	Medium	66.7	0.0	25.0	14.3	25.0	40.0
4	Large	33.3	0.0	0.0	14.3	75.0	20.0
5	Very large	0.0	0.0	25.0	42.9	0.0	20.0
Lower Molar Cusp 6		M1 (n=3)	M2 (n=2)	M3 (n=3)	M1 (n=6)	M2 (n=4)	M3 (n=5)
0	Absent	33.3	100.0	0.0	33.3	25.0	0.0
1	Much smaller than Cusp 5	0.0	0.0	0.0	0.0	50.0	40.0
2	Smaller than Cusp 5	66.7	0.0	33.3	16.7	0.0	40.0
3	Equal to Cusp 5	0.0	0.0	0.0	16.7	25.0	0.0
4	Larger than Cusp 5	0.0	0.0	66.7	0.0	0.0	20.0
5	Much larger than Cusp 5	0.0	0.0	0.0	33.3	0.0	0.0
Lower Molar Protostylid		M1 (n=7)	M2 (n=11)	M3 (n=13)	M1 (n=7)	M2 (n=8)	M3 (n=5)
0	Smooth	14.3	54.5	61.5	28.6	0.0	40.0
1	Pit	85.7	36.4	15.4	71.4	75.0	60.0
2	Fissure	0.0	9.1	15.4	0.0	25.0	0.0
3	Fissure + groove	0.0	0.0	7.7	0.0	0.0	0.0
4-7	Higher expressions	0.0	0.0	0.0	0.0	0.0	0.0
Lower Molar Root Number		M1 (n=6)	M2 (n=11)	M3 (n=11)	M1 (n=1)	M2 (n=3)	M3 (n=4)
1		0.0	0.0	0.0	0.0	0.0	0.0
2		50.0	90.9	100.0	100.0	100.0	75.0
3		50.0	9.1	0.0	0.0	0.0	25.0

APPENDIX 2. *INTER ALIA* DERIVATIVES BETWEEN 47 OLD WORLD SAMPLES
(BASED ON MMD DISTANCES SUPPLIED BY TURNER)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1. West Africa	-																
2. Tasmania	.119	-															
3. Japan	.160	.111	-														
4. Hiogo Japan	.159	.135	.032	-													
5. Recent Japan	.159	.123	.031	.015	-												
6. Kanto Japan	.164	.127	.035	.024	.019	-											
7. China	.160	.121	.050	.023	.032	.038	-										
8. Hong Kong	.170	.144	.064	.035	.043	.045	.023	-									
9. Prehist. Taiwan	.187	.157	.082	.055	.061	.059	.039	.024	-								
10. Chinese	.187	.172	.098	.067	.077	.073	.053	.038	.026	-							
11. Leang Codong	.185	.151	.089	.065	.069	.070	.053	.039	.033	.037	-						
12. Philippines	.192	.183	.113	.086	.092	.092	.070	.052	.035	.024	.043	-					
13. Recent Thai	.188	.179	.121	.094	.101	.098	.078	.061	.046	.033	.041	.017	-				
14. Borneo	.188	.181	.132	.104	.112	.112	.091	.074	.062	.052	.056	.033	.025	-			
15. Early Thailand	.189	.185	.135	.111	.116	.115	.094	.079	.065	.052	.057	.035	.024	.018	-		
16. Java-Malay	.186	.179	.136	.114	.118	.115	.096	.080	.067	.055	.053	.036	.027	.020	.018	-	
17. Ket	.223	.205	.136	.110	.119	.116	.094	.076	.059	.041	.064	.032	.040	.055	.049	.051	-
18. Nepal	.206	.205	.148	.123	.129	.127	.119	.090	.072	.059	.069	.043	.035	.039	.032	.030	.036
19. Tinian	.176	.171	.137	.115	.118	.119	.097	.082	.069	.059	.059	.044	.034	.032	.030	.032	.062
20. Guam	.148	.148	.122	.106	.105	.106	.076	.073	.068	.062	.071	.055	.047	.044	.045	.045	.080
21. Hawaii	.190	.176	.134	.111	.116	.114	.091	.077	.062	.053	.051	.040	.031	.038	.028	.030	.048
22. New Zealand	.172	.164	.129	.108	.112	.110	.087	.074	.061	.051	.050	.042	.041	.051	.042	.041	.060
23. Marquesas	.178	.168	.138	.115	.119	.103	.099	.086	.071	.063	.062	.046	.036	.039	.030	.037	.063
24. East Polynesia	.179	.177	.144	.123	.127	.113	.107	.097	.079	.070	.071	.056	.047	.044	.034	.037	.063
25. Tahiti	.177	.167	.139	.115	.119	.120	.098	.085	.073	.069	.067	.060	.043	.050	.043	.043	.071
26. Fiji-Rotuma	.200	.197	.161	.131	.136	.137	.117	.100	.062	.071	.071	.054	.043	.032	.027	.035	.056
27. Loyalty Isles	.204	.196	.165	.133	.139	.138	.121	.110	.086	.070	.075	.057	.048	.040	.031	.030	.055
28. West Polynesia	.172	.164	.153	.130	.134	.135	.117	.103	.089	.079	.059	.071	.061	.054	.049	.051	.077
29. Jomon	.169	.157	.130	.102	.108	.108	.087	.074	.065	.057	.062	.048	.043	.043	.045	.046	.069
30. Tsukomo Jomon	.187	.178	.155	.132	.136	.135	.111	.099	.092	.078	.079	.067	.059	.052	.048	.047	.068
31. Australia	.134	.143	.142	.117	.121	.119	.103	.094	.086	.085	.080	.076	.072	.067	.062	.064	.100
32. Early Malay Arc	.133	.145	.146	.131	.127	.130	.109	.100	.098	.091	.087	.086	.077	.064	.070	.070	.105
33. Andamans	.160	.160	.161	.143	.143	.144	.122	.112	.103	.091	.115	.082	.073	.062	.061	.056	.092
34. Old Nubia	.101	.137	.147	.128	.129	.134	.118	.115	.118	.115	.113	.113	.106	.095	.099	.099	.140
35. New Britain	.109	.137	.140	.126	.128	.134	.116	.109	.107	.104	.105	.104	.103	.091	.091	.093	.132
36. Sri Lanka	.184	.167	.148	.132	.137	.139	.120	.107	.100	.110	.084	.078	.072	.064	.059	.053	.084
37. Egypt	.165	.170	.160	.144	.152	.147	.124	.126	.118	.106	.110	.098	.088	.080	.078	.070	.105
38. Solomons	.100	.085	.119	.109	.114	.120	.106	.106	.119	.120	.104	.123	.124	.118	.122	.122	.147
39. SW Jomon	.138	.121	.104	.096	.101	.106	.103	.102	.101	.096	.076	.093	.093	.100	.097	.095	.112
40. Yoshiko Jomon	.139	.134	.117	.112	.116	.123	.118	.116	.099	.089	.084	.087	.067	.094	.090	.088	.105
41. Hokkai. Jomon	.142	.123	.098	.090	.092	.099	.096	.094	.097	.091	.077	.125	.095	.102	.095	.089	.108
42. Ainu	.147	.137	.123	.111	.112	.119	.118	.116	.119	.113	.105	.116	.120	.126	.116	.105	.126
43. NW Europe	.150	.131	.115	.106	.110	.113	.104	.103	.102	.096	.089	.100	.105	.102	.096	.090	.111
44. New Guinea	.148	.127	.130	.118	.124	.130	.119	.117	.110	.112	.110	.115	.113	.116	.111	.105	.130
45. Early Denmark	.122	.130	.131	.120	.122	.132	.108	.104	.121	.114	.111	.117	.114	.116	.111	.104	.128
46. England	.113	.122	.129	.121	.120	.131	.129	.128	.134	.136	.131	.146	.145	.144	.142	.136	.160
47. Holland	.109	.140	.154	.144	.146	.155	.155	.158	.175	.177	.167	.189	.190	.189	.183	.181	.204

	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
18. Nepal	—																
19. Tinian	.049	—															
20. Guam	.065	.032	—														
21. Hawaii	.035	.032	.045	—													
22. New Zealand	.049	.038	.045	.025	—												
23. Marquesas	.046	.028	.031	.027	.028	—											
24. East Polynesia	.042	.031	.038	.028	.032	.021	—										
25. Tahiti	.056	.040	.042	.032	.036	.028	.035	—									
26. Fiji-Rotuma	.038	.031	.054	.042	.048	.037	.039	.045	—								
27. Loyalty Isles	.037	.037	.057	.037	.042	.035	.032	.042	.023	—							
28. West Polynesia	.036	.041	.047	.052	.051	.040	.041	.049	.044	.036	—						
29. Jomon	.054	.032	.036	.041	.038	.038	.045	.043	.046	.048	.042	—					
30. Tsukomo Jomon	.051	.043	.051	.046	.048	.044	.044	.056	.045	.040	.042	.030	—				
31. Australia	.085	.058	.038	.064	.062	.047	.057	.057	.037	.070	.048	.051	.068	—			
32. Early Malay Arc	.092	.062	.050	.075	.074	.064	.069	.073	.069	.072	.046	.052	.063	.037	—		
33. Andamans	.072	.056	.053	.067	.066	.054	.057	.065	.056	.053	.042	.053	.052	.040	.033	—	
34. Old Nubia	.119	.095	.072	.112	.102	.072	.096	.094	.107	.108	.086	.086	.101	.049	.048	.065	—
35. New Britain	.117	.085	.064	.095	.088	.064	.083	.087	.101	.099	.075	.080	.092	.043	.051	.063	.033
36. Sri Lanka	.056	.058	.053	.059	.062	.049	.068	.063	.067	.050	.049	.055	.053	.060	.068	.050	.090
37. Egypt	.083	.077	.070	.079	.084	.071	.070	.079	.080	.069	.061	.077	.072	.054	.052	.038	.072
38. Solomons	.142	.110	.091	.120	.110	.109	.117	.110	.132	.129	.098	.092	.112	.079	.074	.095	.068
39. SW Jomon	.104	.087	.071	.085	.073	.078	.080	.084	.104	.098	.074	.073	.086	.065	.072	.074	.083
40. Yoshiko Jomon	.088	.080	.066	.079	.067	.069	.072	.082	.095	.088	.066	.064	.072	.059	.060	.061	.074
41. Hokkai. Jomon	.099	.086	.070	.081	.070	.075	.078	.091	.105	.105	.078	.070	.077	.076	.079	.080	.097
42. Ainu	.112	.088	.091	.100	.095	.099	.097	.109	.126	.113	.094	.096	.099	.085	.086	.087	.096
43. NW Europe	.100	.091	.077	.085	.081	.084	.084	.095	.110	.098	.079	.083	.087	.074	.075	.071	.089
44. New Guinea	.115	.103	.089	.097	.093	.096	.096	.108	.125	.115	.091	.096	.100	.079	.077	.085	.071
45. Early Denmark	.115	.107	.091	.087	.096	.098	.098	.111	.126	.116	.093	.096	.102	.082	.077	.078	.068
46. England	.149	.137	.115	.133	.128	.122	.127	.141	.141	.148	.126	.131	.134	.110	.105	.110	.086
47. Holland	.194	.179	.161	.172	.170	.172	.171	.184	.182	.195	.165	.171	.167	.150	.146	.154	.119

	35	36	37	38	39	40	41	42	43	44	45	46	47
35. New Britain	—												
36. Sri Lanka	.086	—											
37. Egypt	.072	.041	—										
38. Solomons	.071	.119	.111	—									
39. SW Jomon	.071	.084	.090	.077	—								
40. Yoshiko Jomon	.054	.074	.077	.078	.036	—							
41. Hokkai. Jomon	.086	.071	.090	.077	.048	.046	—						
42. Ainu	.082	.075	.078	.094	.058	.057	.051	—					
43. NW Europe	.080	.060	.059	.085	.055	.059	.048	.036	—				
44. New Guinea	.060	.087	.080	.079	.064	.060	.064	.043	.046	—			
45. Early Denmark	.060	.086	.062	.080	.066	.059	.065	.045	.037	.032	—		
46. England	.080	.113	.095	.080	.079	.079	.073	.051	.057	.046	.037	—	
47. Holland	.118	.158	.142	.110	.114	.112	.111	.090	.102	.086	.084	.050	—