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The Hansel and Gretel Syndrome

A Critique of Houghton's Cold Adaptation Hypothesis and an Alternative Model

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ABSTRACT

Houghton's view that the Polynesian phenotype evolved in response to cold conditions encountered during voyaging and in other aspects of small island dwelling is challenged. An alternative hypothesis is outlined, which takes into account a number of variables including diet, disease, and sexual selection for large size. Potential effects of these variables are analysed, with reference to their influence on the Polynesian phenotype. Houghton's model is overly simplistic and unicausal, as real phenotypic change is a far more complex process than he acknowledges.

Key Words: POLYNESIA, PHENOTYPE, COLD-ADAPTATION, SEXUAL SELECTION, DIET, DISEASE.

INTRODUCTION

This paper analyses Houghton's (1990) attempt to explain the evolution of the Polynesian phenotype. After an overview of his cold adaptation hypothesis, relevant climatic, genetic and osteological evidence is examined. An alternative model is then proposed, which may assist in developing an overall picture of how and why the distinctive Polynesian phenotype evolved.

Polynesians, unlike Melanesians and Micronesians, are a reasonably homogeneous biological entity (Howells 1973, 1979; Green 1989; Houghton 1990). Shared morphological characteristics include large body size and muscularity, distinctive pentagonal-shaped head, rocker mandible, oval-shaped fovea, bowed long bones, angle of the femur neck, and relatively short lower limb:trunk ratio, although not all Polynesians have all of these characteristics (Marshall and Snow 1956; Howells 1979; Houghton 1990). Several theories have been proposed to account for their biological origins (e.g., Howells 1973; Bellwood 1978; Houghton 1990).

Early European observers commented on the large size of the Polynesians. Cook wrote that the "Natives of this Country are a Strong, raw-boned, well made, Active People, rather above than under the common size, especially the Men" (Cook quoted by Houghton *et al.* 1975: 325). He was by no means alone in this opinion: "The New-Zealanders are generally tall and well-made; men of 6ft. high are by no means uncommon" (Du Clesmeur quoted by Houghton *et al.* 1975: 325). There is substantial agreement that both in prehistoric and historic times, the Polynesians were an unusually large and robust group of people.

The question is—how did this large size come about? Neither Melanesians nor South-east Asians, the two postulated ancestral populations, are known for their large size. This has led to a belief that the key to the evolution of the Polynesian phenotype lies within Polynesia itself (Terrell 1986).

Houghton concurs; however, he disputes the widely accepted view that the Polynesian oceanic environment is generally hot and humid. In fact, he maintains that it is quite the

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opposite: "this oceanic world can effectively be considered one of the coldest of global environments" (Houghton 1990: 29). He therefore views the large body build of the Polynesians as an adaptation to the cold. From the results of experimental tests, he concludes that this phenotype would have had a crucial selective advantage on long, physically stressful voyages; it would also be a useful adaptation to small island dwelling. Houghton argues that Polynesians were not fat but muscular, and that their muscularity functioned well in maintaining heat-balance in both cold oceanic and warm tropical conditions. He notes that features such as robusticity, brachycephaly, and short lower limbs, characteristic of Polynesians, are found in many cold-adapted populations. This robusticity has in turn shaped the distinctive Polynesian head form and dentition. Houghton argues that the islands of Melanesia were an ideal place for the evolution of this body form before the group expanded into the wider Pacific (Houghton 1990).

There are a number of difficulties and inconsistencies within Houghton's argument. The majority of these centre around his contention that the Polynesians evolved from one of the varied populations in Island Melanesia. Several important questions need to be addressed.

1. If the ideal place for the evolution of this body form is Island Melanesia, why have the populations now living in that region not similarly evolved?

2. Why do Polynesians have so many South-east Asian genes?

3. How could Polynesians have evolved *before* leaving the voyaging safety net (Irwin 1989: 174) of Island Melanesia, i.e., before encountering the very conditions which supposedly provoked phenotypic selection?

4. Why are Polynesians phenotypically closer to Indonesians and South-east Asians (e.g., Pietrusewsky 1990b; Howells 1989) than to the Melanesians from whom they supposedly have evolved?

These questions and others will be discussed in the sections below, each of which examines a particular aspect of Houghton's hypothesis. I hope to illustrate that there is a crucial difference between the Lapita phenotype—as exemplified by material from islands such as Watom—and the phenotype which evolved *within* Polynesia once colonisation had taken place. The former is characterised by very tall, 'slender built' (Katayama 1990), 'typically gracile' (Pietrusewsky 1989: 235) individuals who "enjoyed a quite healthy life with an excellent subsistence strategy to rich coastal environments" (Katayama 1990). The Polynesians themselves, however, are usually described as being tall, robust and frequently obese (Howells 1979). What is the reason for this marked difference in robusticity between the two populations? Where and why did this new phenotype evolve? This paper sets out to answer these basic questions.

BIOLOGICAL AFFINITIES

The orthodox view is that the Polynesians, along with the Micronesians, originated from South-east Asia (Birdsell 1972; Bellwood 1989). Both populations have a number of facial features characteristic of Mongoloid populations (see Howells 1989; Birdsell 1972; Coon and Hunt 1966). Melanesians, on the other hand, from whom Houghton supposes the

Polynesians to have evolved, are too phenotypically distinct from Polynesians to be the source of an ancestral population. As Howells notes, the Polynesians are "simply too different from anything in Melanesia to be derived therefrom by local change in a few thousand years" (Howells 1973: 228).

Multivariate analyses bear these conclusions out. In a study of Pacific populations, Pietrusewsky (1990a) found Micronesians closely aligned with Polynesians, both populations falling within a larger grouping of South-east Asian samples, well differentiated from Melanesian groups. He argues that this conclusion is supported by earlier work in dental morphology, craniometry, anthropometry and genetics. The differences between "Melanesia ... and Polynesia are of such a magnitude" that there is "little, if any, evidence from physical anthropology to support a Melanesian source for either Micronesians or Polynesians" (ibid.: 399). An analysis by Brace and others concurs with this although, unlike Pietrusewsky, they did not find such clear-cut distinctions between Micronesians and Polynesians (Brace *et al.* 1990: 337). They postulate that the "original source of the Austronesian speakers of the Pacific—the Polynesians and Micronesians—may have been the Japanese and Ryuku archipelago" (ibid.: 323), on the basis of strong craniometric links between the former two populations and the Ainu and Jomon of Japan. An "*in situ* transformation of Melanesians into Polynesians is the least likely explanation" (*idem*), in view of the time required (approximately 30,000 years) for such a transformation.

In spite of the obvious affiliations between the Micronesians and Polynesians, a common question anthropologists have been unable to answer is "why Polynesians should have become so relatively enormous, while Micronesians are more like Southeastern Asiatics in general build" (Birdsell 1972: 495). The height and overall robusticity (involving muscularity and often also obesity) of the Polynesians is not mirrored in the Micronesians, who are of moderate height with little tendency towards obesity (*idem*). This is crucial in establishing why the Polynesians look the way they do. I hope to show in this paper that the differences in phenotype between Polynesians and Micronesians are largely cultural in origin, and result from selection in Polynesia, on aesthetic grounds, for a large, obese phenotype, and from the dietary modifications which were undertaken to achieve this. It is the emergence of this phenotype that is outlined in the alternative 'Hansel and Gretel' model below. Houghton fails to distinguish between the robust and gracile phenotypes, treating them as one. Consequently there are a number of difficulties with various aspects of his hypothesis.

VOYAGING

Houghton (1989a: 229) argues that "to settle Polynesia with a group *evolved* from one of the varied populations of Island Melanesia makes the simplest plausible thesis"[emphasis mine]. However, if this body form evolved in Melanesia, why do we not see any evidence of such a robust phenotype in Melanesia? On the contrary, in Melanesia short bodies are the general rule (Howells 1973: 35). Most men average around 160 cm, with others reaching up to 165 cm (ibid.: 161). Swindler (1962: 16) agrees, stating that in Melanesia in general, stature averages around 162 cm. Even coastal populations, who would be expected to voyage the most widely and regularly, are still relatively short. For example, Howells (1943: 41) notes that the entire coastal portion of the western half of New Guinea is inhabited by a single racial group which is short and dolichocephalic, 160 to 165 cm in stature (an estimate which seems to be generally typical of the races he considers, ibid.: 40ff.).

Melanesians, and the Lapita people in particular, voyaged widely. In Island Melanesia, the special wealth of the Lapita communities lay in their skill at long distance ocean voyaging and their ability to make sea-worthy vessels necessary in establishing communities over a vast area (Green 1982: 12).

The coastal areas of Papua New Guinea and nearby islands, for example, are "encompassed by a series of maritime trading systems which also reach out to link it with the Pacific to the east, Asia to the west, and Australia to the south" (Allen 1982: 197). Even relatively early in Pacific prehistory (approximately 3000 B.P.), Lou Island in the Admiralties was supplying the people of Balof Cave with obsidian, a distance of about 320 miles, mostly across open sea (ibid.: 198). In other words, the Melanesians, and particularly the Lapita people, were constantly undertaking voyages which Houghton believes led to the evolution of a large phenotype in the Polynesians, without developing a similar phenotype. This calls into question the need to adapt physically to this type of environment. The tall robust phenotype of the Polynesians, which Houghton believes is necessary for, and a result of, frequent voyaging in Melanesia, is simply not seen in the Melanesians themselves.

Houghton implies that the Polynesians were entirely at the mercy of the cold, wind and waves, without the means to keep themselves warm: "in conditions at sea the early Polynesians were effectively naked" (Houghton 1990: 25). This is unlikely to have been the case. It is questionable whether Polynesians, with their sophisticated navigational knowledge and sailing techniques, were incapable of accomplishing the relatively simple task of keeping themselves warm. Oliver (1974: 196) notes that the larger Polynesian canoes were fitted with special structural features for particular purposes. For example, on long voyages it was usual to construct a platform on which to sit, sleep or cook. For protection from wind and cold weather, some boats had mat work canopies. Thus voyagers would not have been constantly exposed to the wet-cold conditions as Houghton suggests.

Irwin (1989: 168) argues that the corridor running between Island South East Asia and Melanesia was a perfect nursery for learning sea-going skills. Near Oceania, including the Bismarck Archipelago and the Solomons, is an area of relative safety as far as voyaging is concerned; the islands are comparatively large, and one island is not lost sight of before another is reached. The climatic conditions are also favourable. The area lies between belts of tropical cyclones to the north and south (ibid.: 169), and because of seasonal reversals of winds and currents, two way voyaging is a relatively simple matter. The Polynesian phenotype is unlikely to have evolved in Melanesia in the manner Houghton claims, as the selective forces he emphasises are essentially absent. The voyages were too short—around three to four days in duration—and too safe for there to have been great numbers of people lost at sea (ibid.).

In contrast, Remote Oceania constitutes a very different situation. The islands in this region are smaller and further apart. If any type of selective pressure was to occur in voyaging, it would most likely be here, *during* the voyage from Melanesia to Polynesia. For Houghton's hypothesis to be viable, natural selection at this stage must have been very hard and large numbers of people must have been lost during the voyage. Irwin (1989: 168) maintains, however, that the Polynesians had "a navigational technology which allowed them to live rather than die if they followed a simple survival sailing strategy". He envisages "a number of small mutually reinforcing populations supplying their own recruits as they went" (ibid.: 169). There was not enough time, nor were there sufficient numbers, for extensive human wastage at sea (ibid.: 170).

Voyages were deliberate, as the colonisers brought with them domesticated plants and animals (Irwin *et al.* 1990). There is an essential difference, therefore, between exploration and colonisation. A voyage of exploration "has only a point of origin" (Irwin 1989: 173) and therefore it was necessary either to search and discover, or search and return. Successful voyages carried back information about the position and orientation of the islands and the conditions which existed there. Once the exploratory voyage was complete, it would be a comparatively easy task to set out on a voyage of colonisation, taking all the essential elements required to set up a new settlement. Little selection would occur under such circumstances.

Perhaps the most important problem with Houghton's hypothesis is that he fails to explain adequately where, exactly, the Polynesian phenotype evolved. It is unlikely to have been in Island Melanesia as Houghton claims, as this implies that the phenotype developed *before* people were exposed to the very conditions which supposedly provoked its selection. The phenotype is also unlikely to have developed in Polynesia itself. If the colonisation was a two-way process, settlement occurred within the context of continuing communication and gene flow. "Back-communication is maintained after settlement, which allows reinforcement of new communities and the movement of material and ideas" (Irwin 1989: 182). Once exploration had taken place, further colonisation events would be relatively rapid and successful as the voyagers knew where they were going, how to get there, and what conditions to expect on the way—all of which could be prepared for. If there was any initial selection during voyaging it would soon be mitigated by the later influx of people from the original homeland and other islands in the region. In Polynesia itself selective pressure would be negligible, as there is no necessity to adapt to short voyages such as fishing trips. Lives are unlikely to have been lost in this situation. If it is argued that selective pressure did occur here, such pressures should be greater with movement into Eastern Polynesia, as the islands are further apart, and not as readily accessible (Irwin 1989). It would therefore be expected that body size would increase from west to east. This does not appear to be the case, however. Prehistoric Tongans (e.g., Pietrusewsky 1969) appear to be just as large and robust as prehistoric Hawaiians (e.g., Snow 1974).

CLIMATE

The hypothesis that phenotype is influenced by climatic variables is supported by a vast amount of literature dating back to Allen's and Bergmann's rules in the nineteenth century. These rules concern the relationship of surface area to volume, and have been illustrated in populations from many areas of the world. Schreider (1975), for example, claims that people can be seen to exist in ecological gradients linked to climate and thermoregulation. Bergmann's rule states that populations in colder areas tend to be bulkier (i.e., shorter and more compact) than those living in warmer areas. Allen's rule adds that protruding parts of the body, for example limbs and ears, are relatively shorter in cold regions than warm ones. Thus in cold regions these adaptations reduce heat loss as they decrease surface area in relation to weight; in warm regions they increase surface area in relation to weight, thereby increasing heat loss (Campbell 1988: 498–499). For this reason, tall, slender individuals such as Australian aborigines are found in hot environments, while short bulky individuals, such as Eskimos, live in cold environments.

Polynesians, however, fall into neither of these categories. Although tall, they are by no means slender, which suggests that they are adapted to neither cold nor hot conditions. Houghton's hypothesis falters at this point, as it rests on the specific premise that the

Polynesians were not obese. This assertion is false and is countered below. Houghton contends that the reason

> for arguing against pronounced subcutaneous fat deposition as a selective feature in Polynesians is the lability of the oceanic environment ... it is frequently very hot ... and a substantial cloak of fat would often have been an uncomfortable garment (Houghton 1990: 28).

He goes on to argue that subcutaneous fat was not adaptive in cold environments. Fat "is probably to be regarded as little more than a fortunate benefit provided by a food store" (Keatinge quoted by Houghton 1990: 28). In fact, he maintains, adaptation to wet-cold conditions has been shown in several studies to lead to a reduction in the amount of subcutaneous fat (ibid.: 28). Stini (1981) agrees, and claims that Eskimos are not fat, but lean, as are many other populations in cold climates. Individuals from human populations in hot climates often have as much, or more, subcutaneous fat than Eskimos. Thus, if fat is not advantageous in hot conditions, nor is it an adaptation to cold environments and, as contended below, Polynesians *were* obese, Houghton's hypothesis is undermined by his own evidence. If people have less fat in cold environments and Polynesians were fat, then the Polynesians are not adapted to the cold. It has also been shown that larger, more robust, and fatter body types have a greater susceptibility to hyperthermia during exercise in a warm humid environment (e.g., Wyndham 1973). Therefore, the adaptive relationship between body type and climate is very complex, and individuals may not be optimally designed for a particular environment, although they may live within it quite successfully.

Brachycephalisation has also been attributed to climatic variables. Variation in the cephalic index of modern populations is argued to be partially the result of adaptation to cold during the Pleistocene. Extreme cold is typified by a number of factors: moderate stature and nasal index, a round cranium, and lateral body build (Beals *et al.* 1983: 436). Beals *et al.* (1984) argue that head size is more highly correlated with climate than any of the normative measures of body size, and thus cranial morphology may be more influenced by the thermodynamic environment than body size as a whole. They conclude that present-day endocranial volume is at least partly explained by thermoregulation.

The cranial module statistics for Polynesia stand out for a number of reasons. First, there is no correlation between temperature and head size. The inhabitants of the warm islands of Hawaii, for example, would be expected to have a smaller cranial module than those living in the colder environment of New Zealand. However, the opposite is the case. Hawaiians consistently have the largest cranial module of any of the world's populations at 157.3, while New Zealand Maori have a comparatively moderate figure of 151.8. Other island populations such as Tongans and Society Islanders, at 155.6 and 151.7 respectively, are equally anomalous (Pietrusewsky 1984). In a measure of uniqueness in cranial morphology amongst world populations by Pietrusewsky (ibid.), the figures for all Polynesian populations were high, Hawaiians being *the* most unique population. Polynesians, therefore, do not conform to Bergmann's or Allen's rules with respect to either body size or head size. Thus it appears that there is little evidence to support the view that they are adapted to their immediate climatic situation at all.

One alternative explanation is that the observed patterns are a result of nutritional differences. A relatively recent somatometric study of modern Japanese populations by Kouchi (1983) is relevant to this issue. Although Houghton argues that the brachycephaly of Polynesian populations may be a result of cold-adaptation, Kouchi found that cephalic index was highly correlated with dietary pattern (ibid.: 79). He argues that the cephalic index is not as stable as was once thought, being considerably influenced by environmental factors, which resulted in the Japanese growing taller and more brachycephalic in the years between 1910 and 1940 (ibid.: 79). He concludes that environmental factors, including improved nutrition and medical care, are likely to be behind this secular trend, as any partial correlation between temperature and body weight becomes insignificant when the intake of nutrients is kept constant (ibid.: 49). It is notable that the most 'culturally advanced' region, the 'Kinki' district, is also distinctive for the tall stature and brachycephaly of its inhabitants, and that this secular change is probably related to change in food intake (ibid.: 80).

How does this relate to Polynesia? As argued above, the Polynesians are one of the world's most brachycephalic populations, yet there is no apparent correlation between temperature and head size. Therefore, to what can this phenomenon to be attributed? Selection for obesity and the nutritious diet of the Polynesians may have played major roles in establishing head size, as well as body size, in the population. The range of figures seen in Polynesia may be partially explained by regional dietary differences. An interesting possibility for future research would be to examine inter-island variation in nutrition, temperature, body size and head shape in Polynesia. I would postulate that a significant correlation between diet, brachycephaly and body weight would be revealed.

The degree to which climate affects phenotype is by no means well understood. At least one study has concluded that a climatic explanation cannot be the sole adaptive factor (Beals *et al.* 1983: 436). This is supported by Stini (1981: 107) who argues that humans are not really physiologically adapted to severe cold. He notes that even the Eskimo rely more heavily on technological and behavioural, rather than physiological, adaptations when dealing with the cold.

In Houghton's scenario, it is even questionable whether large muscular individuals would have been any better off than their smaller counterparts over long distance voyages. He argues that in exposed conditions "the larger phenotype is better off but for any individual such exposure is unsustainable for more than an hour or so" (Houghton 1990: 26). If shelter is obtained from the wind "the large phenotype can just maintain heat balance. The small phenotype remains in deficit" (ibid.: 27). When paddling, "During such moderate exercise both phenotypes would be still in considerable heat imbalance" (*idem*) under wet-cold exposure conditions. The colonising voyages over the Pacific would have taken a number of days if not weeks; under the severity of conditions that Houghton describes, it appears unlikely that either phenotype would survive.

THE GENETIC EVIDENCE

In *Watom: the people*, Houghton states that the model he is using is one in which

> the dominant settlement of Polynesia was from Island Melanesia, by a group that was part of the human population of that geographic region; that is, they were not in transit through Melanesia from more distant parts (Houghton 1989a: 229).

Serjeantson and Hill (1989: 287), however, argue that

> the extreme view ... that Polynesians evolved within Melanesia from a population resident there for at least 30,000 years, is untenable in the light of the genetic evidence. It seems quite implausible that a group evolving within Melanesia could have acquired by chance, so many non-Melanesian genes!

Houghton nonetheless claims that his model is supported by two types of evidence. One is his own work, which he says has demonstrated that the distinctive Polynesian morphology is "a crucial selective adaptation to the particular conditions of the oceanic environment" (Houghton 1989a: 229). The other is gene mapping. He maintains that the latter reveals "some unique relationships between human groups in Melanesia and Polynesia" (*idem*). This it does, but the geneticists he quotes do not support his interpretation of the data; i.e., that Polynesians were resident in or evolved in Melanesia. Instead, they conclude that the ancestral homeland of the Polynesians is South-east Asia. The authors of one of the articles Houghton cites state that their results showed:

> affinity with Melanesia—but also with Southeast Asia, which has the highest previously reported frequencies ... it seems possible that this chromosome may have been brought into eastern Melanesia by the original mongoloid pre-Polynesians ... studies of DNA polymorphism promise to be very useful in identifying the precise origin of the pre-Polynesians who migrated into eastern Melanesia some 3000–4000 years B.P. (Hill *et al.* 1987: 460–1).

In other words, they remained in Island Melanesia long enough to pick up some genes unique to both populations, but the geneticists almost unequivocally deny they evolved there.

Serjeantson and Hill (1989) make some interesting comments on the debate. They argue that the pre-Polynesian homeland is South-east Asia on the basis of genetic markers shared by the two populations, including the triplicated ζ globin gene arrangement and the type I and IIe α globin haplotypes. At some point it is probable that there was a significant amount of gene exchange with Melanesians, mainly in northern Island Melanesia (Serjeantson and Hill 1989). However, the evidence points to the Polynesians having a hybrid gene pool from Melanesia and South-east Asia (e.g., Hill *et al.* 1987). This conclusion is supported by the results of HLA gene analysis (Hertzberg *et al.* 1989; Serjeantson 1989), which shows that while Polynesians and Island Melanesians share some HLA genes, there are additional distinctive HLA-A9, Bw22 and HLA-A2, B40 linkage arrangements present in Polynesians. The latter also differ from Melanesians in that they have significant frequencies of the α globin gene haplotypes Ia and IIa. Hertzberg *et al.* conclude that the Polynesians were a relatively small, independent colonising group derived from an ancestral East Asian population. In sum, I am unable to find a genetic hypothesis to support a Melanesian origin.

The geneticists also maintain that founder effect and genetic drift probably had a significant effect on the Polynesian populations (e.g., Kirk 1989; Trent *et al.* 1986; Hill *et al.* 1987). The effect of small populations being isolated by geographic and cultural barriers can be seen from studies of Bougainville Island (Howells 1973). Although it is only 250 km long and 65 km wide, neither the geography nor the population genetic structure is uniform. The different geographic regions have developed social interaction patterns which are influenced by geographic and economic resources; these in turn have influenced the biological characteristics of the populations (Kirk 1989). Genetic drift and the founder effect may account for many of the biological differences between the Polynesians and their ancestors. If migrants are a select group rather than a random sample, and are then genetically isolated from other populations, a new phenotype may come into existence (Hulse 1971).

Although many other factors such as environment and culture must be taken into account, the phenotype of the Polynesians may be predominantly the result of the isolation of a small migrant population which, for one reason or another, was already in the larger range of phenotype. Interbreeding between these individuals would eventually result in a larger, morphologically distinct phenotype. The original large phenotype may be purely the result of people consciously selecting strong healthy individuals to participate in the migration. Other selective pressures, such as climate, may only have had minimal effect.

THE ANTHROPOMETRIC AND OSTEOLOGICAL EVIDENCE

Houghton (1990) bases much of his argument for cold-adaptation in Polynesians on anthropometric data from relatively recent Polynesian populations. However, in addition to the fact that these figures are not necessarily an accurate reflection of the body form of Polynesian populations in prehistory, or of their Lapita predecessors, the conclusions he subsequently arrives at are not adequately supported by his empirical data. For example, having compared the stature/weight ratio for cold regions, including Finland and Iceland (ratios under 2.6), with warmer areas such as Burma and India (with values above 3.2), he implies that the Polynesians, with ratios between 2.21 and 2.34, have adapted to the cold to an even greater extent than the populations in a cold climate. Houghton's use of the weight/surface area ratio is similarly flawed. Such reasoning is not justified from the data. The most that can be reliably ascertained from these ratios is that Polynesians are unusually heavy for their height and surface area, an observation which can be explained by a multitude of factors, including diet and social selection (discussed below). The fact that the Polynesian figures are such an anomaly in itself implies that climate is not the causal variable in this instance.

In his analysis of the osteological material from Watom Island (and also that of the Labeka material from Fiji, Houghton 1989b), Houghton fails to acknowledge that many of the characteristics in this Lapita sample which are consistent with Polynesian morphology—such as the rocker jaw—are not "exclusive to Polynesians but are generally typical of most Pacific populations" (Pietrusewsky 1989: 241). In an analysis of non-metric features in Pacific populations, Pietrusewsky (1984) illustrates that the rocker jaw occurs in high incidences everywhere in the Pacific, one of the highest frequencies being found in the Purari Delta in Papua New Guinea (97 percent). That a number of the Watom individuals have a rocker jaw therefore tells us very little—this feature could just as easily link them to Melanesians. Other characteristics cited, such as 'robust' limb bones and tall stature, are also not exclusive Polynesian traits, and are influenced by the environment to such an extent that any hypotheses employing such features must be made with great caution. To claim from such fragmentary data that "this large body phenotype, inappropriate to the land-dominated tropical environment to the west, places the Watom people firmly with other large-bodied ocean voyagers and small-island dwellers, whose most evident living representatives are the Polynesians" (Houghton 1989a: 230), is unrealistic.

The robusticity of the limbs in itself is questionable. Although Houghton argues that they are "moderately robust, and bowed to accommodate a considerable musculature" (Houghton 1989a: 223), Pietrusewsky on the basis of a robusticity index argues that the bones are "typically gracile" (Pietrusewsky 1989: 235).

The age of this material is also crucial. As the material dates to *after* Polynesia was settled, its relevance to the question of Polynesian origins is debatable. Pietrusewsky states that the comparisons indicate that the people of Watom are, in some respects, similar to Polynesians but that "they further exhibit striking morphological differences, such as small teeth, gracile long limb bones and broad short mandibles not seen in other Pacific populations" (Pietrusewsky 1989: 235). He argues that his analysis lends support to the view "that Polynesians are *not* of Melanesian origin" [italics mine] (*idem*). He adds that comparisons based on such small samples provide little in the way of definite conclusions.

Pietrusewsky's non-Melanesian origin hypothesis for the Watom population finds parallels in a study of another Lapita sample. Kirch *et al.*, in an analysis of Lapita skeletal material from the Mussau Islands in Melanesia, suggest that "Mussau Island Lapita people had slightly closer affinities with Indonesian than with Melanesian populations" (Kirch *et al.* 1989: 63), although this conclusion was formulated largely on the basis of dental remains. For example, the upper incisors show shovelling which, while rare in Melanesia, is common in Indonesia and Polynesia. The authors believe that if Lapita was a product of local evolution within Melanesia, it would be expected that the Mussau teeth would show a higher frequency of Melanesian than Indonesian characteristics. Such a trend is not apparent in their sample.

AN ALTERNATIVE MODEL FOR THE ORIGIN OF THE POLYNESIAN PHENOTYPE

One may challenge Houghton's hypothesis on the basis of his assumption that the Polynesians were incapable of reacting to their environment in a logical manner. He implies that climatic influences were the only ones to affect the Polynesian phenotype substantially. Phenotype, however, is affected by a multitude of different factors (Dobzhansky 1970). In the case of modern *Homo sapiens*, to argue that one factor in particular is responsible for all or most of the observable characteristics of a population is questionable. Determination of factors affecting phenotype must take into account all possible influences including genetic, ecological, physiological and cultural.

CULTURAL SELECTION

Humans are distinguishable from all other species by their degree of cultural development. Dobzhansky (1972: 84) suggests that "man's adaptedness depends more on his cultural than on his genetic inheritance" and it has been argued that "natural selection by itself is neither adequate nor appropriate for explaining the culturally acquired phenotypic traits of human beings" (Durham 1978: 428–9). Certain features, such as large size, may be actively selected for by members of a particular population. In this section, I aim to show that the selective environment of the Polynesian phenotype was partly moulded by cultural and ideological variables. A variety of factors, including diet, active selection of sexual partners, the polygamous marriage system, size as a status symbol and certain rituals associated with food consumption, as well as non-cultural variables such as climate, may all have combined to produce the Polynesian phenotype.

Darwin first advanced the hypothesis that selection for an aesthetically pleasing phenotype could have important evolutionary implications. He concluded that "of all the causes which have led to the differences in external appearance between the races of man ... sexual selection has been the most efficient" (Darwin 1901: 925). He suggested that

> if it can be shewn that the men of different races prefer women having various characteristics ... [and vice versa] we have then to enquire whether such choice, continued during many generations, would produce any sensible effect on the race ... (Darwin 1901: 873).

He argued that in

> civilised and semi-civilised nations sexual selection has effected something in modifying the bodily frame of some of the members ... Cook remarks that the superiority in personal appearance "which is observable in the erees or nobles in all the other islands (of the Pacific) is found in the Sandwich Islands" (Darwin 1901: 894).

If each isolated tribe developed a different standard of beauty, then phenotypic divergence would occur. This is what I wish to argue in partial explanation of the difference in robusticity and muscularity between the Polynesians and their ancestral population.

As differential fecundity is "as powerful a selective agent as differential survival or mortality" (Dobzhansky 1970: 97), those whose children survive to reproduce in the greatest numbers are those who will largely determine the direction of phenotypic change in a population. Although most people in tribal societies mate and produce offspring, those who are more influential, such as chiefs, may not only have more potential and actual sexual partners, but are also able to provide better environmental conditions, thus increasing the chances of offspring surviving to maturity (Dobzhansky 1972). Differential fecundity has been noted in many populations. For example, among the Xavante, some men produce very few offspring and others make significant contributions to the gene pool. In one village, one headman's contribution to the present population totalled twenty-three surviving children (Chagnon *et al.* 1970: 345).

The type of marriage system practised is also thought to have an effect on the population. Wolfe and Gray (1982) looked at the mean height measurements for males and females in 140 different human societies. Their results indicated that there was a statistically significant positive correlation between a high mean male height and polygyny. In a comparison of generally polygynous societies with 'ecologically imposed' monogamous societies and those with limited polygyny, mean male and female heights were significantly greater in the former at all levels of protein availability. The tallest males and females were found in societies with high protein availability; thus diet appears to be a significant factor also. The authors offer several possible reasons for this outcome (Wolfe and Gray 1982: 226). Taller males may have a greater presence of being than shorter males, thus obtaining an advantage in sexual relationships with females. If taller males are associated with leadership qualities they may accumulate more wives and father more offspring than shorter males. In addition, if taller males are perceived by females as being healthier or more capable providers than shorter males, they may again gain a reproductive advantage over their shorter counterparts.

Wolfe and Gray conclude that there are a multitude of causes of intersocietal variation in stature, and that any account of the differences must take into consideration nutrition, climate, marriage practices and assortative mating.

THE POLYNESIANS

In the following sections data will be presented to demonstrate that multiple factors affected the evolution of the Polynesian phenotype. Houghton claims that

> There is no doubt that Polynesians have a strong tendency to obesity in westernized conditions but evidence that obesity existed in the past is lacking in the historical record (Houghton 1990: 28).

This is not true. There is abundant evidence in the historical record to show that not only were Polynesians frequently obese, they were deliberately so. A large size was considered beautiful in many Polynesian societies, and was a characteristic actively selected for.

AESTHETICS

Danielsson (1956: 70) notes that "to be regarded as perfect, a Polynesian woman must first of all be stout. The stouter the better." He quotes Sir Basil Thomson's detailed description of the Polynesian ideal of beauty, based on Thomson's experiences in Tonga in the late nineteenth century:

> the perfect woman must be fat—that is most imperative; her neck must be short … She must have no waist, and if Nature has cursed her with that defect she must disguise it with draperies … her bust and hips and thighs must be colossal. The woman who possesses all these perfections will be esteemed chief like and elegant (Danielsson 1956: 70).

The King of Tonga at that time had an explanation of his own, according to Thomson: "the human eye demanded a sufficiency in the things presented to it; if they were insufficient, it found them ugly" (*idem*). Similarly, the Tahitians believed stoutness to be a mark of beauty characteristic of royal personages, and thin persons were thought to be sick (Teuira Henry quoted by Oliver 1974: 358).

As a result of this attitude, people on some Polynesian islands were deliberately fattened, usually on preparations of especially rich fruit and vegetables. In Tahiti this procedure was called *ha apori* which means fattening. *Ha apori* was a universal and ritualised episode usually performed on both males and females during their teens, and was often combined with skin-bleaching. Large numbers of youths would present themselves before the *ari'i*, or chiefs, and were then shut in one of the large sheds on the island where they were provided with as much food as they could eat. During this time, which was usually a period of several months, they did not get up except for the necessary bodily functions, and slept as much as they could in order to get as fat as possible. They were then displayed in parades for public appreciation (Oliver 1974: 434–437). On Mangareva (Buck 1938), the first born sons and daughters of the chief were brought up in *'are 'akarau* (fattening houses). A large size and fair complexion were considered the physical attributes of chiefly rank; therefore the first born sons of chiefs were secluded and fed on the best food. In spite of the hardships endured in order to become fat,

> they all wanted to be submitted to such a regime because, during the rest of their lives, they felt the benefit of the period of fattening. They were always stronger and stouter than the others and hence came the idea that to be a good looking man and a great chief it was necessary to have a large stomach and big limbs (Buck 1938: 117).

The inhabitants of this island also held beauty contests. Those who won such events came to be known as the *porotu* (handsome people). For such people

> conquests in love were easy, because the youth of either sex were only too eager to be associated with a person who was known as a *porotu* ... The choices made at beauty shows were either temporary love affairs or developed into marriage (Buck 1938: 128).

The well-fed beauties or *hakarau* were made so fat, that at the parade they were

> supported by their relatives because—even fatter than carnival bulls—they could not walk without stumbling or collapsing under their own weight ... There were seven or eight of them at every feast, but the fattest one was always the last to be exhibited. As they appeared before the crowd anxious to see them, the people shouted with sheer admiration and the one who aroused the most admiration was considered the champion (Buck 1938: 118 quoting Laval).

A similar procedure was followed in Pukapuka (Beaglehole and Beaglehole 1938: 282). The sacred maid in Pukapuka was either the first born child of a chief or another girl of the chief's lineage. She represented the cultural ideal of womanhood in the society although, because of her sacred status, she was barred from marriage. The other fattened youths, however, were expected to make good marriages: "Only a man who was a good fisherman ... could hope to get a fat, fair wife, and only a fat woman would be able to get a *kaitau* husband" Beaglehole and Beaglehole 1938: 282). Fattening rituals were also carried out on Easter Island (Metraux 1971: 104).

A number of explanations of this custom have been put forward for Tahitian society: for example, that forced fattening embodied the Tahitians' Lamarckian theories of reproduction and served to implement their eugenic ideals. However, "it was also quite directly and overtly cosmetic, ... and, in the young, at least, sexually relished" (Oliver 1974: 437).

Fatness, and a large body size in general, were directly selected for in choosing a partner. Oliver notes a practice by "some women, usually upper class ones, of copulating with tall and well-built males to help ensure that the offspring they subsequently bore ... would also be tall and well-built" (1974: 353). Polynesians were thus aware of the workings of the reproductive process to the extent that they realised that physical characteristics of parents could be passed down to their children. Their own concept of this, however, was Lamarckian, as can be seen from the great efforts that were often made to fatten young women before marriage and childbearing. Thus it appears that there was sexual selection in both sexes for those with a larger phenotype. Over a relatively short period of time in small colonising populations, directional selection for body size could have a significant impact on the average phenotype in the population. As Darwin argued, it is noticeable that the chiefs and the upper classes in general in Polynesian societies are larger and better favoured than the other classes of the society. One early observer noted that

> the chiefs, and persons of hereditary rank and influence in the islands, are, almost without exception, as much superior to the peasantry or common people, in stateliness, dignified deportment and physical strength, as they are in rank and circumstances; … This is the case with most of the groups of the Pacific … Their limbs are generally well formed, and the whole figure proportioned to their height; which renders the difference between the rulers and their subjects so striking, that some have supposed they were a distinct race … (Oliver 1974: 782–3, quoting Ellis).

This disparity between the two classes Ellis correctly attributed to the "different treatment in infancy, superior food, and distinct habits of life" (*idem*).

The Polynesian chiefs and other high status individuals, as in most polygynous societies, had greater access to wives and/or sexual partners than the majority of the population. In Tahiti, Oliver notes that many of the inferior chiefs had two or three wives. In contrast, higher chiefs had a system of concubinage where many lovers were taken.

> When the rank of the parties was equal, they often separated; the husband took other wives, and the wife other husbands; and if the rank of the wife was in any degree superior to that of her husband, she was at liberty to take as many husbands as she pleased (Oliver 1974: 463, citing Ellis).

In Samoa, chiefs of high rank married many times to link their families and villages to other important families and villages. Because chiefs had many wives (some as many as 50), there were not enough women available for every man to marry. Therefore some men would have never married and fathered children (Meleisea and Meleisea 1987: 25). This is significant, as it means that there could have been a great deal of sexual selection occurring, with those who were aesthetically more pleasing having a better chance of securing a wife and fathering children. It is likely that among the common people, also, the more attractive, i.e., larger, men and women would be able to obtain more partners.

STATUS

Large size was also a sign of status.

> Few of the Chiefs are shorter than Six feet, but many of them exceed that height by some inches, for this reason they readily believed Captain Cook and such of His officer as were tall stout men were Chiefs, but they have no Conception that a short man can be a Chief (Morrison 1935: 169).

A well-fed and healthy chief in Polynesia was a sign of prosperity and the beneficence of the gods, and represented the fertility of the people and the land. The chief was (and still is) the people, and his/her well-being reflected theirs (Rutz 1989). This belief was so powerful that it is still apparent in Polynesia today. In a study of perception of associations between body size and behaviour in a group of contemporary Samoans, Baker *et al.* (1986) made some interesting observations. When asked to identify high status from a group of pictures depicting fat and thin individuals, both men and women perceived the obese individuals to be of high status, and the lean of low status. When the group was asked to identify the most effective chief, 80 percent chose the most obese phenotype. The main reason they gave for their selection was that larger men commanded the most respect and appeared more regal (ibid.: 196). As thin people were thought to be ill (see above), it was important for chiefs and other high status individuals to cultivate as large a body size as possible, thus maintaining the respect and faith of their constituents. To appear otherwise might be a sign that they had lost the support of the gods. This explains the chronic obesity of many chiefs as noted by the early explorers. Levy notes that a Spanish expedition in Tahiti reported: "the *ari'i* … are all stout, some of them to ungainliness, so that they have two Indians constantly kneading their legs, and even then are scarcely able to stand upright" (Levy 1973: 110, citing Corney).

DIET

Diet must be taken into account in any consideration of the Polynesian phenotype, and the disparity in the amount and quality of the foods eaten possibly accounts for the difference in size between the chiefs and the commoners.

It appears that in Polynesia eating had both symbolic and communicative roles.

> The lives of all Polynesians … rotated around one central theme—the production, distribution, and consumption of food … a concern with food permeated Polynesian life at all levels of the social ladder and in all social dimensions (Kirch 1984: 29).

Eating in great quantities and especially being fed by others was a sign of status. As a result, chiefs were fed copious amounts of food (Levy 1973). George Forster, an early visitor to Tahiti, described visiting

> a very fat man, who seemed to be the chief of the district … a woman … near him crammed down his throat by handfuls, the remains of a large baked fish, and several breadfruits … His countenance was the picture of phlegmatic insensibility … all his thoughts centred in the care of his paunch (Levy 1973: 109).

At various times of the year when breadfruit was most plentiful there were great feasts, and the whole population ate excessively. During this time "people seldom quit the house … it is surprising to see them in a month or so become so fair and fat, that they can scarcely breathe: the children afterwards grow amazingly" (Oliver 1974: 221, quoting James Wilson). Even the poorer people were not excluded from this method of feasting; if they did not have enough breadfruit, their neighbours would assist and the two families would make an oven between them (Morrison 1935).

There are a number of determinants that affect infant growth, including genetics, disease and nutrition (Baker *et al.* 1986: 227). It has been suggested that there is a definite association between infant/childhood/adolescent fatness and adult weight (ibid.). A tendency towards obesity in contemporary Samoans may begin at birth with a predisposition towards rapid weight gain. This high weight accumulation is continued into early childhood (ibid.). In Tahiti, the fattening process was begun when the children were babies, and William Ellis noted that "infants were … plump and healthy in appearance" (Oliver 1974: 428). Much emphasis was placed on the physical well-being of the children in an aesthetic sense, rather than on their behavioural advancement. Babies were fed on *poipoi*, a rich mixture of mashed breadfruit and coconut cream, as early as possible, since the first few months of life were considered crucial for the fattening process (ibid.: 427). Most Polynesian societies were characterised by people who were healthy, well-fed, and disease-free. For example, Samoans of all classes were described by the early European visitors as being a tall and healthy people who enjoyed a high standard of living with abundant food (Meleisea and Meleisea 1987: 25).

Good nutrition, therefore, may well have added to the height and weight of Polynesians. It is known that "under conditions of high protein availability, people are more likely to reach their genetic growth potential than are people living in low protein situations" (Gray and Wolfe 1980: 452). Societies with poor protein availability tend to have a low mean male height (ibid.).

The precontact diet of most Polynesians consisted of taro, yams, coconut, bananas, breadfruit, and occasionally pigs and chickens. Regular protein was provided by exploitation of reef resources. Thus it was similar to that of horticulturalists throughout the world, with two major exceptions. First, the combination of ocean and reef resources, and root and tree crops, gave an adequate supply of protein and energy which reduced the chances of malnutrition common amongst other horticulturalists. Second, because of the use of coconut, the diet was probably higher in saturated fat than is typical in other horticultural populations (Baker *et al.* 1986). While in most populations a shift to a modern diet is usually accompanied by an increase in stature, this does not occur amongst Samoans, for example, who show no increase in stature with dietary change (ibid.: 277). This view is supported by Ducros in a study of secular trend in height amongst Tahitians, which concluded that the mean height had remained remarkably stable (Ducros 1980: 205) between the early 1900s and the present day. He maintains that they had already established the right conditions to attain the maximum genetically-determined height because of a diet rich in calories and proteins over a long period of time (ibid.: 205). This suggests that the Polynesians have achieved their optimum genetic potential for height on a traditional diet—something the eighteenth century Europeans had not managed to do (see below).

It has frequently been noted in Melanesia that there is a marked difference in stature on some islands between inland and coastal populations. New Guinea Highlanders (Howells 1973), whose small size is thought to be due to a low protein, high fibre diet, increase significantly in size on moving to the coast. After several years their size increases to around 65 kg, substantially greater than the 49 kg they could expect to attain had they remained in the highlands. Their appearance often changes so substantially as to make them virtually unrecognisable to their relatives. A 'bush/beach dichotomy' (Friedlaender 1975: 28) has been noted on Bougainville Island also, where populations living near the coast are taller and longer headed than those in inland areas.

In a study of ecological factors affecting the growth of pre-school children in Papua New Guinea, Malcolm found that the quantity of food intake is the major determinant of size, particularly in the six months to two years period (Malcolm 1974: 191). Malcolm argues that another ecological factor affecting growth is the cultural attitude of society to childcare and feeding. In Papua New Guinea, for example, eating is determined almost entirely by the choice of the child, who eats when and what he/she wants to. In the early weeks of life the child cries and is breast-fed on demand. Beyond six months, however, the child's ability to demand or obtain food is inadequate to maintain sufficient nutritional intake. Only when children are over two years old are they sufficiently vocal and mobile to satisfy their own needs.

> Mothers appear reluctant to actively encourage their children to eat food at any age … mother[s] [believe] … that, as the child does not want to be fed, he should not be compelled to (Malcolm 1974: 193–4).

This is very different from the situation existing in Polynesia, where there is a great concern by mothers to feed their children, by force if necessary, at all ages until adulthood. This may have a profound effect on the growth of Polynesian children, who have no developmental hiatus but are supplied with nutritious food throughout their lives.

The dietary hypothesis has been supported by findings from studies of Japanese populations. Much of the data on weight gain in Japanese migrants to the United States comes from a Honolulu heart study in 1974, which illustrated a gradient of increasing body mass and skin-fold thickness among Japanese men living in Japan, Hawaii and California. All the differences between the populations were ascribed to environmental variables, especially diet (Baker *et al.* 1986). Ohyama *et al.* (1987) in a study of 738 Japanese medical students in Japan over a 20 year period, discovered that means of standing height, leg length, and the ratio of leg length to standing height increased, although over the same period, the mean sitting height x 100/standing height had declined. The authors attribute this secular increase in growth to greatly improved nutritional standards, especially in terms of the energy ratio of proteins, fats and carbohydrates, which underwent a remarkable change in the Japanese diet over the time period (Ohyama *et al.*1987).

A study in the changes in growth between Japanese American children and those born in their native country was undertaken by Greulich (1976). It was discovered that while Japanese Americans were originally significantly taller, heavier and longer legged during childhood, a change had taken place when the same individuals were re-measured as adults. Although still taller and heavier overall, they were found to be comparatively shorter legged than their Japanese counterparts.

Houghton has argued that the limbs of *Homo sapiens* will be

> relatively shorter and stouter in the colder parts of the species range. The short-legged Eskimo[s] … may be contrasted with some long-limbed African negro groups … The Polynesian sitting height ratios greater than 51 indicate that the considerable stature is derived from a long axial length and relatively short lower limbs (1990: 24).

This, like most other Polynesian characteristics, he attributes to the cold oceanic environment to which they have adapted. However, this comparative difference in leg length in the Japanese Americans, whatever the cause, was certainly not due to the cold. The greater overall height can be attributed to the more favourable environmental conditions in which the American children were reared (Greulich 1976). It is more likely, therefore, that the comparatively short leg length in Polynesians is purely an allometric factor, resulting from their Asian origin, and is not correlated with climatic variables.

Houghton himself has noted that other populations have grown a considerable amount over the last one hundred years (Houghton *et al.* 1975). For example, the median height of the conscripts into the army of the Netherlands has risen by nearly 140 mm (5.5") in the last century (ibid.: 325). Similarly in France, the average height of members of the army was 5 feet 5 inches (ibid.: 325), which is certainly less than the figure would be today. Whatever the reason for this substantial increase in growth, it was not an adaptation to increasing cold. Improvements in health and nutrition would probably be widely accepted as the major contributory factors (e.g., Ducros 1980). Roberts (1981: 124–125) notes that the secular increase in height in modern populations has been too rapid to be attributable to natural selection, and that it is more likely to be the result of improved nutrition, health and hygiene. This increase in European populations over one hundred years is possibly equal to, or greater than, the difference in height between the average Melanesian and Polynesian populations today.

The Polynesian diet has a high degree of protein (Baker *et al.* 1986) and it appears from all accounts that the environmental circumstances under which the chiefs were reared resulted in a larger, more robust phenotype. The lower classes also appear to have fared comparatively well. If disparity in the standard of diet is accountable for the differences within the population, then it is also quite likely that it accounts for inter-population differences as well.

DISEASE

Another possible contributory factor to the large size and general good health of the Polynesians is the comparative lack of disease, at least until the arrival of the Europeans (Stannard 1989). This is in contrast to many populations of the Pacific, such as the Melanesians, which have a high rate of endemic diseases such as malaria. These can have a devastating effect on the population. Swindler (1962) notes that all Nakanai are suffering from this disease, which is responsible for large numbers of deaths, especially during the first five years and up to puberty. Endemic malaria results in

> acute and chronic physical disability, … a high infantile mortality rate … and it has a direct and indirect influence upon nutrition … any facet of the life of the indigene in a malarious country must be viewed against a background of chronic malaria (Black 1956: 136).

Under such circumstances, it is unlikely that an individual will reach his/her full genetic potential for growth. Specifically, malaria affects the brain and causes anaemia, which in itself is sufficient to cause death. Other parts of the body affected include the bone marrow, spleen, liver, kidneys, adrenals, lungs, and gastro-intestinal tract. There is a physiological chain reaction leading at first to reversible and then to irreversible tissue changes in extreme cases (Edington and Gilles 1974). It is a well-established fact that sub-optimal nutrition affects an individual's resistance to infection and that infection in turn impairs nutritional status, although the impact of infection *per se* on growth remains to be established (Malcolm 1974: 194). It has even been suggested that "malaria—which occurs in Melanesia but not Polynesia—may have helped to shape the physical contrasts between their modern inhabitants" (Kelly 1990: 216, citing Keesing and Keesing). Relaxation of this selective pressure allowed the Polynesians to become more muscular and fatter.

HANSEL AND GRETEL VS THE COLD ADAPTATION HYPOTHESIS

What are the advantages of the alternative model? I am not arguing that Houghton's model is necessarily wrong, and the alternative model right. What has been shown here, however, is that there are some inconsistencies within Houghton's argument which need to be addressed before the hypothesis can seriously be considered. One of its major problems is that it considers climatic variables to the exclusion of other, equally important influences, such as culture. Culture is *Homo sapiens*' most important means of adaptation, and must not be ignored in any explanation of phenotypic traits. In addition, Houghton's (1990) empirical data provide an inadequate foundation upon which to base his claims. The major aim of this article is to point out that the observation that larger people survive longer in cold water than small ones, does not constitute proof that the Polynesians are adapted to the cold. There are a multitude of other factors such as diet, disease, and social selection which may have contributed to the phenotype of the Polynesians.

Both hypotheses are testable. For example, if phenotype were related to cold adaptation, it would be expected that a larger, more robust phenotype would be found in islands such as New Zealand, which can be bitterly cold, than on Hawaii or Tonga which are relatively warmer. I would argue that in fact this is not the case. To test the dietary hypothesis would require nutritional data from prehistory to be gathered from a large number of Pacific islands, and then tested against the skeletal evidence. It may be possible to do this using isotope and trace element analysis of bone. If the 'Hansel and Gretel' hypothesis is correct, one would expect to see a more robust phenotype in islands with better nutrition. If it were possible to obtain skeletal remains from high status individuals, a phenotypic difference should again be evident, as those individuals were fed large amounts of the best foods (see above). This is, one hopes, a project for the future.

CONCLUSION

Cultural factors have had, and continue to have, a substantial and significant influence on the phenotype of the Polynesians. The prestige associated with strength and obesity was, and to an extent still is, ingrained in the ideological structures of Polynesian societies. A large person is considered aesthetically pleasing and of high status. For chiefs, large size is associated with the well-being of the people they govern. These values have affected the modern phenotype in two major ways. First, large size was consciously selected for when choosing a marriage partner, and thus those with this particular phenotype (especially high status individuals) were more likely to donate a greater percentage of their genes to the next generation. Over time, as differential fecundity has more effect on natural selection than differential mortality, the phenotypic and genotypic nature of future generations would be altered. Second, a highly nutritious diet, combined with the lack of disease in prehistoric Polynesian populations, allowed the population to reach its full genotypic growth potential.

Houghton's model has paid insufficient attention to the cultural factors affecting Polynesian populations and their history, and as a consequence has some serious internal inconsistencies. The Lapita phenotype is *not* the same as the Polynesian phenotype and should not be considered as such. The great robusticity of the Polynesians is likely to have developed through cultural selection only after they had been resident in Polynesia for some time. I believe that climate is unlikely to have been a major determinant of the Polynesian phenotype. At no point in the alternative model is it argued that the Polynesian phenotype is an adaptive feature. In fact, it could be argued that the Polynesian phenotype is maladaptive in that it results in obesity-related diseases, and requires a higher level of nutrition to maintain an adequate body-weight, thus putting greater pressure on an island's resources. Humans do not necessarily respond rationally to their environment. Rather, their existence is a complex of ideological, cultural as well as practical responses to life, which do not necessarily serve any useful function. This is exemplified by the 'Hansel and Gretel' type fattening rituals which used up precious food resources for cosmetic reasons alone. It may have been the new environment in which the Polynesian ancestors found themselves which allowed them to develop their distinctive phenotype, but it was ultimately cultural variables which produced it. The alternative model is advantageous in that it looks at a whole range of variables, which may be investigated more fully in the future.

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