

## Coming of age of human adaptability studies in Samoa

*Jim Bindon*

Bindon, J.R. 1997. Coming of age of human adaptation studies in Samoa. In: S.J. Ulijaszek and R.A. Huss-Ashmore (editors). In: Human Adaptability: Past, Present, and Future. Oxford University Press. Pp. 126-156

### **Introduction**

Studies of populations subjected to specific environmental stressors such as hypoxia, hypothermia, or seasonal hypocaloric intake are fundamentally different from studies of populations undergoing the stress of culture change. While the field-work is no easier in the former cases than in the latter, at least there are clear-cut models from ecology, physiology, and nutrition predicting how these stressors operate on human populations. However, in Samoa, where the principal stressor of interest is culture change the predictive models available are problematic in many respects. This chapter begins with a discussion of the adaptation paradigm used in many of the studies done in Samoa, then considers issues of social forces as stressors. Next a review is provided of some of the progress made in 20 years of studies of Samoan response to cultural change, and finally some assessments of this research are offered and some cautions and hopes for the future tendered.

### **Biological background: the adaptation paradigm**

The Samoan Studies Project (SSP) took its direction from the adaptive paradigm as articulated on several occasions by Baker and his students (Baker 1982, 1984a; Little and Haas 1989). This paradigm is based on the comprehensions reached in the 1950s and 1960s as a result of embracing synthetic evolution within anthropology. Drawing from disciplines as diverse as demography and environmental physiology, and the understanding of human adaptation made possible by the International Biological Programme, we generated an initial estimate of what might be expected in Samoa. Working from the central concept of adaptation by natural selection, a model of the historical selective pressures that might have shaped the Samoan gene pool was built. The example of genetic adaptation in human populations based on the sickle cell haemoglobin and malaria system served as a prototype. From other work on Polynesians, a previously existing model for these selective pressures was suggested: Neel's

'thrifty' genotype model (Neel 1962). Selection such as that envisaged by Neel is suspected of being one of the primary shapers of the Samoan gene pool and the health outcomes of modernization among Samoans (Bindon *et al.* 1991; Bindon and Baker, in press). Zimmet (1982) and his co-workers (Kirk *et al.* 1985) have suggested a genetic aetiology for increased prevalence of obesity and diabetes among Polynesian populations, related to enhanced survival of individuals with the 'thrifty' genotype during settlement of the Polynesian Islands. Prior (1977) and Baker (1984b) also endorse this interpretation of the selective forces working on the Polynesian gene pool. These adaptive scenarios focus on the settlement voyages undertaken by the Polynesians, with the expectation that there was a significant genetic bottleneck during the migration to the Pacific islands in a manner similar to that proposed for Native Americans crossing Beringia.

Neel proposed the 'thrifty' genotype model to explain why diabetes occurs at such high frequencies in certain populations (Neel 1962). His model suggests that diabetes results from a genetic predisposition for the efficient utilization of dietary energy from carbohydrates. This efficiency is achieved through the increased uptake and storage of glucose in peripheral tissues, which may be facilitated by a hyperinsulinaemic response to glucose. Enhanced glucose clearance may be due to the extended period of insulin secretion in hyperinsulinaemic individuals (Olefsky *et al.* 1982). In addition to aiding in the transport of glucose into peripheral cells, insulin facilitates energy storage by stimulating the process of lipogenesis (Pike and Brown 1975). Thus, the hyperinsulinaemic response both increases glucose uptake, and promotes energy storage. However, one metabolic consequence of such a sequence of events tends to be a development of insulin resistance, which leads to glucose intolerance and in the most severe cases to diabetes. To understand how the 'thrifty' genotype operates four states of energy balance must be considered: caloric balance, feast, famine, and small chronic excess.

During periods of energy balance, when the calories consumed are approximately the same as the calories expended in activity, individuals with the 'thrifty' genotype would not express diabetic symptoms as long as their activity levels were high enough to prevent any caloric excess. Several studies have shown improved insulin effectiveness and glucose tolerance in response to physical exercise (Minuk *et al.* 1981; Krotkiewski *et al.* 1985). The interaction of physical activity and glucose metabolism appears to operate through increasing insulin sensitivity of the peripheral cell receptors (DeFronzo and Ferrannini 1982). Activity also tends to decrease the amount of insulin released in response to glucose (DeFronzo 1982). Thus, glucose transport is enhanced by activity through increased insulin-binding activity, while at the same time, being in caloric balance would minimize excess circulating glucose, thereby obviating the development of a hyperinsulinaemic response, glucose intolerance, and ultimately diabetes. This state would have been characteristic of Samoans during most of their habitation in the Samoan Archipelago and prior to their voyaging to settle the islands.

During feast periods when caloric intake far exceeds caloric expenditure, hypersecretion of insulin would produce efficient storage of the caloric excess. More of the excess calories would be captured and stored in 'thrifty' persons. The feast state would have occurred occasionally in the normal course of social events in Samoa, and at two other times that relate specifically to potential selection: prior to embarking on an extended ocean voyage and immediately following a crop-devastating storm. At these critical junctures, feast-like consumption would equip the 'thrifty' individuals with a boost to their energy storage.

During times of food shortages, when caloric expenditures exceed intakes, energy that has been stored during previous feasting is available to compensate for deficits in intake. This was the primary force for selection in Neel's model (1962), as he envisaged a hunter/gatherer band undergoing periods of feast and famine, with the 'thrifty' genotype providing an advantage to certain individuals by virtue of their increased ability to store energy for use during times of famine. In this way, natural selection would act to increase whatever genes were involved in the 'thrifty' metabolism, just as sickle cell haemoglobin genes spread in response to the presence of malaria. In addition, metabolic changes occur in times of energy shortage, such as shrinkage of adipose cells and chronic low levels of insulin secretion, that tend to countermand the development of insulin resistance (Olefsky *et al.* 1982). During such famine times the 'thrifty' genotype would have provided two types of selective advantage for the Polynesian voyagers. First, the 'thrifty' individuals would be better insulated from hypothermia during the voyage (Baker 1984b), as they would tend to have larger fat masses and thicker deposits of subcutaneous adipose tissue. This is especially important at sea, where clothes would tend to lose insulating capacity if wet, but adipose stores would keep their heat retaining qualities. Secondly, the 'thrifty' individuals would be likely to have more energy stored in their adipose reserves for use during times of food scarcity, such as during voyages, during settlement of the islands, and during recovery from severe tropical storms. The selective pressure exerted by possible famine is thought to be responsible for shaping the early Samoan gene pool.

If the long-term energy trend is for balance, especially if physical activity is high, the adverse effects of the 'thrifty' genotype would not be expected to manifest. If, in addition, there were times of food shortage, the selective advantage would go to individuals with the 'thrifty' genotype. However, if the long-term trend is for a small chronic positive caloric balance, especially coupled with low physical activity, metabolic changes leading ultimately to the development of diabetes may be anticipated for those with the 'thrifty' genotype. The aetiological sequence of events would begin with chronic hyperinsulinaemia, which tends to decrease the sensitivity of peripheral cell receptors to insulin. This phenomenon is known as insulin resistance, and appears to be a key step in the development of glucose intolerance and diabetes. The primary locus of insulin resistance, even in obese individuals, is the peripheral muscle mass, which accounts for about 85% of glucose uptake,

as opposed to fat mass, which accounts for only about 1% of glucose clearance on average (DeFronzo 1982). Thus, the importance of physical activity to development of diabetes may be mediated in part through physiological and/or structural effects exerted on the peripheral muscle cell mass, as well as metabolic effects. The reduction of physical activity along with chronic excess caloric intake (as evidenced by increasing rates of obesity) has become more frequent among Samoans since the Second World War, predisposing an ever-increasing segment of the population to diabetes.

In summary, it is likely that there was a genetic bottleneck during the settlement phase of the Samoan Archipelago, and that the islanders may well have arrived with a strong tendency for a metabolically 'thrifty' genotype. Selection would have been maintained over the subsequent millennia by periodic crop-destroying storms, and it would have been primarily since the Second World War that social and behavioural changes would have created an unfavourable environment for the energetically efficient in the population, producing a tendency for diabetes.

While this modification of the 'thrifty' genotype model has substantial plausibility, it remains in the realm of the speculative. At no time have members of the SSP attempted to investigate a likely genetic basis or the metabolic sequelae predicted by the model other than to investigate rates of obesity and diabetes. The 'thrifty' genotype provides the only model of genetic adaptation in the SSP. Virtually all of the studies of Samoans have focused on consequences of modernization—an exercise in defining the limits of adaptation—rather than direct investigation of genetic, physiological, or behavioural adjustments to provide homeostasis or reproductive advantage. In this sense, then, the SSP cannot be said to have been an investigation of human adaptation, but rather it has been an examination of adaptive failure, focusing on the health consequences of too rapid social change. If our studies persist long enough, we might be able to detect adaptive processes responding to the stresses of social change, but that has not been accomplished within the project to date.

### **The social background: social change and psychosocial stress**

Baker (1984a) pointed out in his 1982 Huxley Memorial Lecture how behavioural adaptation to stress sets in motion a stress–response dynamic based on biological stresses created by the new behaviour. He gives many examples such as: '... the use of smokey fires in highland New Guinea huts for mosquito protection has created respiratory disease stress . . . while the soft iron pots of many African cooks stress the livers of their epicurians' (Baker 1984a, p. 7). He goes on to document how severe and significant the stresses were that accompanied the development of agriculture. Finally, he discusses some of the biological changes that Samoans go through as they adopt modern life-styles, illustrating the stresses (obesity and disease) caused by the new behaviours.

There is a long and detailed literature about how social forces act to create stress, specifically psychosocial stress, in individuals. This is represented in epidemiological work such as that of Henry and Cassel (1969) documenting how blood pressure increases with age in modern and modernizing societies, but not in those groups less exposed to modern life-styles. The research on type A behaviour patterns as a cardiovascular risk factor (Herd 1978) also supports the importance of psychosocial stress in patterns of health and disease. The work of Jenner *et al.* in Oxfordshire has applied this concept towards understanding physiological processes by documenting the impact of psychosocial stress from managerial and mental work on stress hormone secretion (Jenner *et al.* 1980; Reynolds *et al.* 1981). Recently, a mechanism has been proposed for the association of mental stress with cardiovascular disease based on alterations in blood platelet activity (Malkoff *et al.* 1993).

While these examples document the salience of psychosocial stress for health and illness, one significant problem remains that biomedical and epidemiological studies tend to focus on the individual. However, from social theory, we know that the individual is embedded in a cultural context that guides his/her interpretation of events so that they may be perceived as more or less stressful. This, in turn, will amplify or dampen the physiological ramifications of any psychosocial stress experience. Therefore, to examine social forces as sources of stress, it is essential to use analytic models that incorporate the cultural context. Dressler (1989, 1992, 1995) develops the methodological tie between this social theory and measurement of context, and provides excellent examples of how to conduct contextualized surveys. He points out that at a minimum, we need to know what kinds of behaviour produce stress, how individuals might react to it, and what are the intracultural factors that will differentially affect responses. He emphasizes that these models must be built from an understanding of the ethnography of the group (Dressler 1995). From such an ethnographic understanding the complexity of the context of individuals can start to be unravelled. Individuals relate to their larger cultural context through their immediate community of residence, and they are further contextualized within their community by their membership in a household. In terms of understanding context to derive meaningful research designs, we need to understand the larger culture through ethnography, and we need to comprehend the community in order to be able to derive appropriate samples. Furthermore, we must measure relevant household variables that are likely to affect our outcome variables.

The importance of the community context is emphasized by a recent investigation of the association of community level influences with individual health behaviours, which found that the community exerts significant influences on behaviour and health, even after controlling for many key individual level parameters (Curry *et al.* 1993; Diehr *et al.* 1993). Perhaps even more significantly, in this study of 15 communities in Western USA, the researchers conclude that the community characteristics accounting for behavioural variability appeared to differ from one community to the next, further emphasizing the importance of the community context of behaviour.

In most societies the household acts as an intervening level between the individual and his community having the potential to both reduce and increase stress. Households are usually composed of individuals related by marriage and consanguinity. These households serve as the locus for economic production in most societies. In order to gain a full understanding of how behaviour affects the health of individuals, the articulation of the individual within their household, the household within the community, and the individual within their household must be investigated. A poster recently presented by the editors of this volume illustrates this point.<sup>1</sup> They presented results describing the effect of household economics on nutritional status among the Wopkaimin of New Guinea and the Swazi of southern Africa. In each setting they found a similar relationship between earning wages and increased body mass index (BMI), but the particulars were different in each community. For Wopkaimin households, average BMI was correlated with the proportion of men currently employed, while for Swazi households, it was related to the number of household women employed. If only male employment, or as is the more common practice, household head employment had been investigated, the significance of the cultural context in this comparison would have been lost. Preliminary study of the ethnography and history of each group, either from literature sources or from a pilot study, should have been able to detail the traditional division of labour and allow prediction of how the household might respond to increasing engagement in a wage economy. Even if such predictions are incorrect, allowing the ethnography to determine what to measure makes it much more likely that the researchers will end up with an accurate picture of the situation.

Several techniques to measure the phenomena of cultural change have been devised over the last two decades within the social sciences. During this time, much attention has been paid to the cultural context of change and to the level of measurement of responses to change. Dressler (1995), in a review of biocultural models in anthropological research, provides further explication of these issues drawing examples from Samoan studies of blood pressure and stress hormones and from his own research on cardiovascular disease risk factors in developing societies. The interested reader is urged to see this review for amplification and clarification of points relevant to these topics.

### **The Samoan Studies Project**

The SSP evolved from discussions between P. T. Baker, J. M. Hanna, and others, that developed in 1974 into a resolve to investigate the biological consequences of social change among Samoans. The decision to work with Samoans was partly fortuitous, based on existing associations with Samoans in Hawaii and a previous study conducted by Hanna in Western Samoa. It was

<sup>1</sup>Huss-Ashmore, R. and S. Ulijaszek, 'Economic Indicators of Household Nutritional Status', presented at the Annual Meeting of the American Anthropological Association in Washington, DC, November, 1993.

also a highly rational decision based on the opportunities the Samoan population presented for biocultural research into social change issues.

Baker (1986) summarized the rationale for studying Samoans as being based on several attractive research design elements. The Samoans were an island population, which suggested that they had been relatively isolated and self-sufficient in the past. An initial presumption that the Samoans were relatively genetically homogeneous was based on this history. In addition, substantial research already existed about the Samoan natural and cultural environment, making possible the building of informed analytic models in the initial research phases, and reducing the amount of original pilot data that would have to be collected. Finally, the social disruption of American Samoa by Second World War and subsequent events, including the migration of a large number of Samoans to Hawaii and the US mainland, distributed Samoans into a number of communities with widely varying social characteristics. This population dispersal made possible cross-sectional research designs that allowed the simulation of process research (see map, Fig. 8.1). By investigating biological outcomes across genetically similar samples with varying exposures to modern life, it was thought that the effects of modernization could be approximated without having to bear the time or money expenses associated with a true longitudinal, processual study. In this section I will discuss several of the projects that make up the SSP, focusing on some of the shortcomings, what was learned, and how the studies could be improved.

From the beginning, one of the key problems faced by the SSP was an adequate operationalization of the concept of modernization. Baker (1986) cited Levy's criteria of modern society, which include a cash economy, a formal education system, secular governance, and urban units (Levy 1966). Baker next noted that most human populations are part of such societies, but segments of populations may participate in modern society to lesser degrees.

In order to make the contrast [traditional versus modern] a usable research tool many investigators, as did those involved in the Samoan research project, have therefore ranked regions, communities, and individuals on comparative scales from traditional to modern ... While these derived scales are useful for categorizing the degree of group or individual participation in the two types of sociocultural systems, it is doubtful that the definitional traits are proximate causes of any health or biological differences (Baker 1986, pp. 7-8).

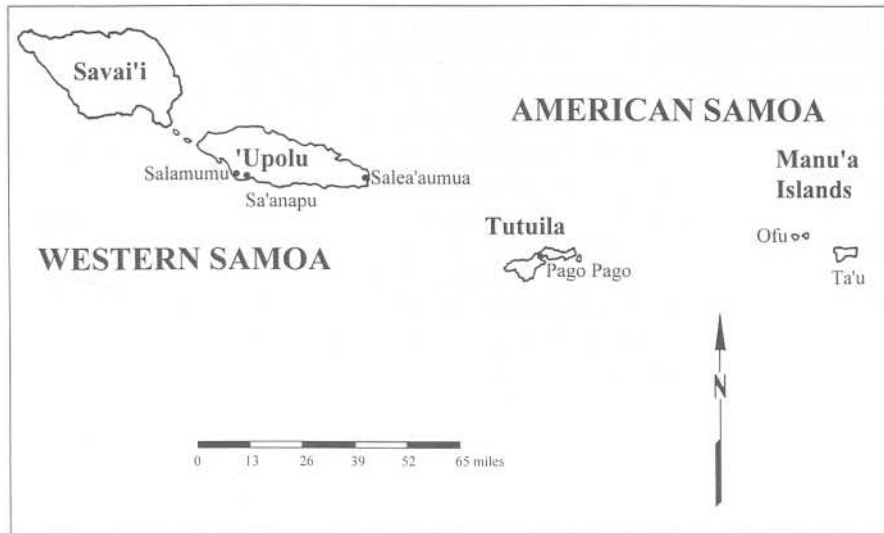
Baker emphasized the divorce of these scales of modernization from proximate causes of biological differences in a hypothetical schema of how modernization may be linked to health outcomes (Baker 1986). In this schema, environmental changes such as participation in a cash economy, diversity of occupational niches, diversity in belief systems, variety of available foods, and diversity of health care are linked through behaviour such as increased tolerance of behavioural differences, increased variation in physical work, greater variety of individual diets, and variation in the effectiveness of medical care to health

variety of questions was used to estimate the parameters of hypothesized significance.

Even when the SSP was beginning to be conceptualized, some of the complexities of the stress processes associated with cultural change were understood (e.g. the work of Henry and Cassel 1969). As a result, some variables in our early field-work were more carefully operationalized than others. In particular, the SSP provided good descriptions of potential stress outcomes: cautiously and precisely measured blood pressure, body weight, and skinfold thicknesses, to name a few. We also gathered a lot of information about individual level predictors of outcomes such as education, occupation, place of birth, and migration history (e.g. see Bindon and Baker 1985). In spite of this, in most studies associated with the SSP the significance of the ethnographic context has been underestimated or compartmentalized as separate from the health-related outcome variables that have been measured. A second and different area of difficulty involves the level of measurement of behavioural phenomena, which fluctuated from the individual to the household to the community, with little consistency in either theoretical viewpoint, methodology, or measurement operationalization. As a result, many studies of modernization effects on biological outcomes among Samoans suffer from poor measurement of modernization. Many of my articles are among the worst offenders in both categories, ignoring ethnographic context and shifting paradigms from community level to individual level measures of modernization without sufficient scientific rationale (e.g. Bindon 1982, 1984a,b, 1995). In spite of, and perhaps also because of these flaws, there is much to be learned from an examination of the SSP.

### *The Samoan setting*

After settlement by the early proto-Polynesians about 3000 years ago, life in the Samoan archipelago (see map, Fig. 8.2) continued to the early part of the nineteenth century, following the traditional pattern of farming and fishing. Archaeologists tell us there appears to be little contact with the outside world aside from some trade networks and possibly mate exchanges with a few other island populations (Green 1979). Western influences in Samoa became significant starting in the 1830s. First missionaries, and later traders and whalers began to become common visitors to Samoa. Colonial interests began to shape political events in Samoa beginning in the 1870s. Conflicts continued between the USA, Germany, and Great Britain until a resolution was reached in 1899. The islands were divided with Germany getting the large islands in the west, the USA controlling the small islands in the east and the British withdrawing. German control of the western islands ended in 1918, when New Zealand included the islands as part of its protectorate in the Pacific. The eastern islands, the Territory of American Samoa, was under the administrative jurisdiction of the US Navy during the first half of the twentieth century.



**Fig. 8.2.** Map of the Samoan archipelago.

From 1900 to 1940, economic development proceeded slowly in both parts of Samoa. The Second World War brought dramatic change to American Samoa, while Western Samoa remained on the periphery of the world affairs. The US Naval Base in the Pago Pago harbour became a very active military facility. During the war, US military troops actually outnumbered Samoans on the island of Tutuila while employment opportunities for the Samoans increased explosively, and unprecedented amounts of cash flowed into the island economy (Lewthwaite *et al.* 1973).

At this time some Samoans left the islands, but during the 1950s, many more migrated out as a major economic depression hit American Samoa. The US Navy withdrew from Pago Pago, and shifted their operations to Hawaii after the war. This meant the elimination of most jobs, with few alternatives to take their place. The Navy transported almost 2000 Samoans to Hawaii or the mainland USA between 1951 and 1956 (McArthur 1967). Rather than remain in Samoa with a diminished income, these Samoans were willing to move to maintain their style of life. The influence of these migrants was felt through the cash and goods that they remitted to their relatives who stayed primarily in American Samoa.

In Western Samoa, agriculture continues to the present to be the mainstay of the economy. Coconut and cocoa still account for almost all of their agricultural exports. Post Second World War demand for goods began to increase as the Western Samoans saw the increased flow of cash and merchandise into American Samoa. However, Western Samoa remains one of the poorest

nations in the world, and much of that demand can only be satisfied by migration to American Samoa.

During the 1960s, economic development in American Samoa took another upturn. Congressional grants-in-aid were substantially increased. In addition, a second large tuna cannery and a can manufacturing plant was opened in 1963, providing employment for thousands of Samoans. The school system was expanded using educational television, which necessitated the extension of electrical power to all villages throughout the islands. Thousands of contract workers were brought from the mainland to work for the Government of American Samoa. Supermarkets and department stores opened to cater to the needs of the contract workers. These markets also increased the access of the Samoans to new foods and merchandise. Most of the food on Tutuila is imported because the American Samoans no longer live off the land. The supermarket has supplanted the plantation as the principal source of food on Tutuila (Booth 1985; Bindon 1988).

Wage employment has supplanted subsistence or market agricultural production in most of Samoa. Many adults in the rural parts of Western Samoa remain farmers and fishers, but it is the rare village that has not been profoundly changed by the introduction of cash, electricity, piped water, and buses. In American Samoa, the changes have been even greater. On the main island of Tutuila, most families now have two adult wage-earners, and there is little reliance on plantation productivity on a daily basis. Samoans living in Hawaii and California have become even more engaged in striving for the middle-class American life-style. This variability of life-style in the different Samoan communities provided the initial research design for the SSP.

#### *Preliminary surveys of Samoans in the different communities*

The initial collaborative surveys were undertaken by students under the direction of Baker at Penn State and Hanna at the University of Hawaii. These projects were broad-based pilot-type community studies, attempting to establish the basic parameters for obesity and health among Samoans in Hawaii (in 1975, 1976, and 1977), American Samoa (in 1976, 1978, and 1982), and Western Samoa (in 1979 and 1982). In addition, Pawson directed a small-scale survey of Samoans in the San Francisco Bay Area (from 1979 to 1983). The maps in Figs 8.1 and 8.2 locate the communities and some of the villages involved in these surveys. In all of these surveys, a wide range of ages for both sexes was sampled, and except for Pawson's sample, all of these surveys had relatively large numbers of adults and children (Table 8.1). Outcome variables were primarily obesity-related, including anthropometrics, skinfolds, and blood pressure. In addition, blood samples were collected in Hawaii in 1977 and American Samoa in 1978 for a test of the central assumption of the project that the Samoans are relatively genetically homogeneous.

Sampling procedures in these preliminary studies varied considerably from site to site, from year to year, and from researcher to researcher. In Hawaii and

California, an opportunistic sampling regimen was used that depended on key informants and assistants to recruit subjects. In Western Samoa, whole village surveys were conducted in rural areas in which 90–97% of the village residents were surveyed. In American Samoa, the 1976 sample included over 40 villages sampled by holding clinics and having public health nurses and village mayors encourage subjects to attend. The 1978 sample was based on key informants, and the 1982 sample was drawn from a well-baby clinic registry. In addition, over a dozen different technicians conducted the measurements in the different settings. As a result, community level analyses of these data are fraught with numerous potential sources of inter- and intra-observer error.

**Table 8.1** Sample characteristics of preliminary studies of Samoans

Community	Sites	Study years	Children ( <i>n</i> )	Adults ( <i>n</i> )
Western Samoa	Villages of Salamumu, Sa'anapu, Salea'aumua	1979, 1982	497	341
American Samoa	40+ villages on Tutuila, Ofu and Ta'u Islands	1976, 1978, 1982	674	1,725
Hawaii	11 urban/suburban neighbourhoods on Oahu	1975, 1976, 1977	556	585
California	San Francisco Bay Area	1979–1983	144	228

Adapted from Bindon and Zansky (1986a) and Pawson (1986). See maps in Fig 8.1 and 8.2

The analytic model in most of these preliminary studies took the form of a general linear model such as:

$$\text{Outcome} = b_0 + b_1 \text{Covariate}_1 + \dots + b_{n-1} \text{Covariate}_{n-1} + b_n \text{Community} + e$$

where the dependent variable was an anthropometric, skinfold, or blood pressure measurement; the covariates were usually limited to age and sex (although skinfold measurements were used as a covariate to predict blood pressure on occasion); and community served as a proxy for modernization. In these analyses, the rural villages of Western Samoa constituted the most traditional sampling area, the Samoan residents of the San Francisco Bay Area were the most modern if included in the analysis, otherwise the migrants in Hawaii were the most modern, and American Samoa (sometimes divided into two or three zones) was considered intermediate for the purposes of modernization. The underlying assumption behind this model is that the community of residence is an acceptable surrogate measure of involvement in a cash economy, increasing diversity of employment, diet, and activity, and decreasing prevalence of infectious diseases.

Because of the confounding of many behavioural and social variables into the one indicator, community of residence, this model provides conceptually and

methodologically the weakest test of the biological consequences of modernization. At the same time, due to the large sample sizes accrued in the different communities, this model provides perhaps too much statistical power. Table 8.2 provides a power analysis based on effect size for weight and triceps skinfolds for comparisons of subjects in Western Samoa, American Samoa, and Hawaii.<sup>2</sup> With the minimum sample size set at the smallest sex-specific sample for the three communities, and establishing large confidence intervals and high power (i.e.  $\alpha = 0.05$ ,  $\beta = 0.05$ ), it can be seen that failure to detect statistically significant differences with this conceptually weak analysis would have been highly unlikely.<sup>3</sup> A difference of less than 2 kg in weight or 1 mm of triceps skinfold using age-adjusted sample means for children aged 4 through 19 has very little biological or social significance.

**Table 8.2** Effect size analysis of analyses of covariance of weight and triceps skinfolds for Samoans living in Western Samoa, American Samoa, and Hawaii

Measurement	Boys	Girls	Men	Women
Minimum community sample size	220	194	142	199
Detectable difference in weight (kg)	1.6	1.8	7.1	6.1
Sample size needed to detect a 5 kg difference	23	26	270	270
Sample size needed to detect a 10 kg difference	—	—	72	72
Detectable difference in triceps skinfold in mm	1.1	1.1	2.5	3.5
Sample size needed to detect a 2 mm difference	10	8	240	540
Sample size needed to detect a 5 mm difference			36	95

Adjusted for covariates: Age and Age<sup>2</sup>.

Effect size and detectable differences are based on setting  $\alpha=0.05$  and  $\beta=0.05$ . Source for calculation of effect size, sample size, and power: Lipsey (1990).

The detectable differences for the adult samples come much closer to being biologically significant, but the effect size and detectable difference is conditioned by the smallest sample, and in the case of the adults, there were nearly 1500 excess Samoans surveyed in American Samoa (i.e. total sample for American Samoa in 1976 was approximately 1700). By contrast, if we had established the 95% confidence interval and power criteria and accepted average differences of 5 kg of weight and 2 mm of triceps skinfold for the children and 10 kg of weight and 5 mm of skinfold for adults as being biologically meaningful, we could have satisfied our sampling requirement with fewer than 60 children and 200 adults from each community. The smaller sample sizes needed to allow the detection of these differences would have allowed more time per subject both for following an appropriate sampling

<sup>2</sup>The data from the California sample were never merged and analysed together with the data from the other communities until preparation of the volume edited by Baker *et al.* (1986).

<sup>3</sup>While we are used to 95% confidence intervals, which is equivalent to setting the probability of a type I error ( $\alpha$ ) to 0.05; 95% power, which is equal to setting the probability of a type II error ( $\beta$ ) to 0.05, is unusually high for biomedical research. This combination provides exceptionally stringent sample requirements.

scheme that could have produced more generalizable results, and for detailed interviewing to provide more in-depth information about participation in modern life-styles.

With the above caveats in mind, some generalizations can be drawn from the preliminary studies. Community level analyses of obesity from these initial surveys found substantial differences between the Western Samoan samples and all other groups for both children and adults, males and females. Samoan boys and girls from Western Samoa were shorter and lighter, with lower BMI and smaller triceps skinfolds than the other children from age 4 to 17 (Bindon and Zansky 1986a, b). This same pattern of differences was present in the adult samples (Bindon and Baker 1985; Pawson 1986). Smaller differences, occasionally statistically significant, were observed between the samples from American Samoa, Hawaii, and California. The primary conclusion from studies of obesity analysed at the community level is that there appears to be a threshold effect, with Samoans in a more traditional setting in Western Samoa exhibiting much less weight and adiposity than those in other communities. Blood pressures taken in these early surveys have the same general trend, with pressures tending to be lowest in Western Samoa and higher in the communities more exposed to modernization, although the pattern is not as clear for blood pressure as for the anthropometric and skinfold measurements (McGarvey and Schendel 1986). No consistent influence of time since migration to Hawaii or California could be demonstrated for the anthropometric, skinfold, or blood pressure measurements. Thus, the basic effect demonstrated by the community analyses is one of modernization as assessed by area of residence.

Different models for dividing up the communities into varying degrees of exposure to modernization have been used throughout the project. In particular, American Samoa has variously been aggregated into one community (Bindon and Zansky 1986a), or disaggregated into two (Bindon and Baker 1985) or three (McGarvey and Schendel 1986) communities. Such disagreement about how to treat a variable that is central to the preliminary understanding of modernization effects is only possible because of the absence of theory-derived measurement models for modernization in these early studies.

How do these findings relate to any concept of adaptation? I would argue that the most optimistic assessment of these studies would say that the results provide a measure of the adaptive limits of the population in the face of changing life-styles. Making the untested assumption that the Samoans were well adapted to their environment with their traditional life-style and had a propensity for metabolic energetic efficiency because of thrifty genes, the obesity-related changes we demonstrated appear to be disease related, not adaptive in nature.

### *Individual level studies*

All of the preliminary studies included questions asking for individual level social information. The most commonly asked questions included those about

the educational background and occupation of the subject, as well as questions about migration history. While the shotgun scatter of questions we asked bore little methodological relationship to any social theory, the answers could be used to construct a better measure of individual exposure to modern life-style than was possible using only community of residence as a crude measure of modernization. Formal education and engagement in a cash economy are two of Levy's (1966) criteria of modern society. Therefore, higher levels of education and cash-based occupations should serve to discriminate between more traditional and more modern individuals.

Education was demonstrated to have little or no association with the anthropometric and skinfold measurements, but occupation and parent's occupation were found to be significantly associated with these measurements, with individuals in more skilled occupations (hence, less traditional) being heavier and fatter, and having heavier and fatter children (Bindon and Baker 1985; Bindon 1996). However, education was found to influence adult blood pressure in a number of ways. McGarvey and Schendel (1986) demonstrated a significant negative association between education and blood pressure for men and women in most residential areas of American Samoa. That is, higher levels of education were associated with lower blood pressures. They viewed this result as somewhat anomalous and difficult to explain.

Occupation, whether categorized into traditional versus modern or separated by activity requirements, was found to be related to both adult size and adiposity, as well as to offspring fatness (Bindon and Baker 1985; Bindon 1996). While McGarvey and Schendel (1986) model occupational effects on blood pressure as mediated through activity levels and adiposity, no analysis of occupation, activity, and adiposity is available to test the postulated pathway.

Migration history, whether measured as time since migration, per cent of life spent in migrant community, or previous migration experience was not demonstrated to exert significant effects on anthropometric, skinfold, or blood pressure measurements, beyond those already documented for residence in Hawaii or California.

While providing some additional resolution of how modernization might operate to influence biological changes among Samoans, the lack of methodological coherency to the variables collected left the social nature of the modernization process largely undocumented. Part of the problem in this process was the creation of different questionnaire or interview instruments by various individuals, all with slightly different research agendas, with little attempt to derive questions about modernization based on social theory as informed by Samoan ethnography or Samoan views of the matter. One of the ironies of the project was that during the first round of survey work in Hawaii in 1975 data were collected on material style of life which could have been used to investigate material culture change with modernization, a potentially fruitful avenue for exploration. However, these data have never been analysed.

### *Genetic homogeneity*

Another important aspect of the early community surveys was the test of one of the basic assumptions of the project about the genetic homogeneity of the Samoans. Parsons (1982) investigated this question using both anthropometric and blood group data on Samoans in American Samoa and Hawaii. The blood group data included seven red cell antigen systems, five serum protein systems, and 21 red cell enzyme systems, and placed the Samoans well within the published ranges for Pacific populations. Overall rates of admixture, as indicated by the presence of European and Melanesian marker genes, were low in her samples. However, the admixed genes were more likely to show up in the migrant sample in Hawaii. Parsons concluded that:

Since the blood genetic data unequivocally indicate genetic admixture in migrants, it is reasonable to hypothesize that this same admixture is at least partially responsible for the distinctive migrant phenotype. Samoans with European- or Melanesian-influenced morphology may be less well integrated into mainstream Samoan culture or may have greater exposure to modernizing or foreign influences, and thus may be more likely to migrate . . . These forces in combination may operate to select for non-Samoan characteristics among Samoan migrants. However, since migration between American Samoa and Hawaii is so massive, fluid, and accessible, only slight differences between migrants and nonmigrants should be expected (Parsons 1982, pp. 268-9).

As a result of Parsons' work, and subsequent genetic analyses by Crews *et al.* (1991), we have continued to operate under the assumptions about relative genetic homogeneity for the Samoans, attributing most biological differences to differences in environmental exposures. However, this assumption has not yet been tested in a survey with adequate sampling of the various Samoan communities.

### *Problem-oriented surveys*

Even as the preliminary community surveys were being completed, more detailed problem-oriented surveys were being undertaken to explore more manageable pieces of the larger problem of the Samoan adaptive landscape. These studies included more in-depth examinations of behaviour, and health-related variables. Most of these studies relied on intensive data-gathering protocols on small samples that tended to be limited in area of residence, age range, and frequently included members of only one sex, in an attempt to control variables not of direct interest to the researcher. Stratification of sampling was then directed along lines to maximize contrasts in areas of interest such as occupation or physical activity.

Detailed studies of the effects of the interaction of modernization and caloric

balance on obesity in Western Samoa have been undertaken by two researchers. Pelletier (1984, 1987) studied diet and activity among men in a rural village and in the capital (Apia) of Western Samoa. He found a pattern whereby both groups of men indulged in substantial excess caloric intake on Sundays (a feasting day from early missionary times in Samoa). However, in the village, the men compensated for the excess by high weekday activity, and a slight negative energy balance throughout the rest of the week. By contrast, the men in Apia were more sedentary, and failed to balance out their Sunday excesses during the rest of the week. This pattern corresponded with the variability in body mass index and adiposity of the two groups of men, with the villagers (the most traditional group) having significantly lower body mass and skinfold values. Schendel (1988, 1989) looked at two aspects of daily activity among Samoan men and women in the same settings used by Pelletier. Schendel found that overall levels of daily energy expenditure and the maximum intensity of activity were associated with obesity, with the Samoans engaging in the most active life-styles with the highest energy-costs being less obese than those pursuing less intense activity. In her sample, the most active group included all rural men, and some rural women, and again followed a general gradient of more modern, more obese, less traditional, less obese.

Work capacity was investigated in Samoan men, and those in more traditional village communities or doing heavy physical wage labour in Western Samoa had relatively high aerobic capacities. Men living in more modern communities (American Samoa and Hawaii), or with more modern life-styles (Western Samoans with sedentary occupations and leisure activities) have very low aerobic capacities. However, physical demands of work tend to be lowest on these men, so their work capability, or the interaction between work capacity and work requirements, is adequate (Greksa *et al.* 1986). No comparable study has been done with Samoan women, or with older men over 30 in Western or American Samoa, so there are still large gaps in our knowledge about work capacity and work capability in modernizing Samoans.

Blood lipids have been investigated in several surveys. Modernization effects on blood lipids have been modelled by investigating either community level contrasts, or through an examination of physical activity effects. However, in none of these studies is a strong case made for an effect of modernization on activity. The community contrasts indicate that total cholesterol tends to be lower in a select sample of young men in Western Samoa than for men in American Samoa and Hawaii, but there is little discernible pattern to the variability in cholesterol levels among both men and women in the latter two communities (Pelletier and Hornick 1986). Triglycerides were found to be highest among both men and women on the main island of American Samoa, Tutuila. In very small-scale studies in Hawaii and American Samoa, total cholesterol was found to be lower among active young Samoan men than among less active or older men (Lukaski 1977; Hornick 1979). By contrast, Pelletier found that Western Samoan men did not vary significantly in total cholesterol according to activity level, but sedentary workers had significantly

lower levels of high-density lipoprotein cholesterol than did traditional villagers. He also found that dietary and alcohol intake, tobacco use, and adiposity showed negligible independent effects on cholesterol levels (Pelletier 1984).

Stress hormone secretion has also been a target of several of the problem-oriented studies. Several researchers have tried to examine the association between modernization and catecholamine secretion. Community level analyses show a tendency for higher noradrenaline levels throughout the daily cycle among men, but less clearly demonstrate this trend for women. Adrenaline excretion rates are relatively high in all Samoan samples, and show a mixed response to community differences, with James finding more modernized young men, especially college students and sedentary labourers in Western Samoa, to have higher adrenaline levels than more traditionally situated men (James *et al.* 1985, 1987; Pearson *et al.* 1993).

Several indices were used to define the psychological and social aspects of modern life-styles. James found that the strongest associations with noradrenaline and adrenaline excretion rates were with urban versus rural residence and with carbohydrate intake. None of the psychosocial indices of modernization proved to be significant correlates of catecholamine excretion. By contrast, Hanna *et al.* (1986) used a categorical analysis of three levels of overnight adrenaline and cortisol excretion and found some interesting psychosocial interactions for a small group of very young men and women in American Samoa. They reported that Samoans showing the highest levels of hormone excretion reported having the least reliance on family members, having fewer people they 'felt close to', and having intermediate levels of community involvement. While using different psychosocial instruments and different statistical techniques, Pearson (1989) found some points of agreement with Hanna *et al.* (1986). Pearson found that noradrenaline was most closely associated with physical activity for both the young men and women that he surveyed in Western Samoa, American Samoa, and Hawaii. He noted that adrenaline excretion was related to psychosocial variables, including per cent of time spent in the household context for women (more time spent in the household, the lower the excretion rate), and per cent of time spent interacting with other individuals outside the household for men (more time spent interacting, the lower the excretion rate). The association for women suggests that modernization would increase the level of hormone secretion. For males, the results are more equivocal as to how modernization would affect secretion.

The reliance of the problem-oriented surveys on small, highly-selective samples provided some excellent tests of narrow hypotheses about specific influences on the various outcome variables. However, the central psychosocial issues of modernization have not yet been addressed with substantial methodological sophistication or rigour. Furthermore, by limiting the age and sex distribution of the samples, some of the ethnographically most salient issues were eliminated from consideration.

### *Social incongruity studies*

One of the principal ways that modernization may impact health is through increasing psychosocial stress. Since the classic paper of Henry and Cassel (1969) a basic notion of how social change might influence psychosocial stress and the age-related rise in blood pressure seen in developed and developing societies has been available. One source of the psychosocial stress has been postulated to be status incongruence (Smith 1967). Status incongruity assumes that discrepancies in social status indicators, e.g. education and occupation, create confusing and ambiguous situations where individuals may react by exhibiting increased blood pressure. In modernizing contexts, status incongruity is likely to crop up in individuals elevated to jobs beyond what their education has prepared them for, as well as individuals who are over-educated for the jobs available to them. McGarvey and Schendel (1986) found education and occupation status incongruity had a significant association with blood pressure only in Samoan men living in a 'most modern' region of American Samoa. No effects were found for men in other areas of American Samoa as well as migrants in Hawaii. No effects were found for females in any of the areas. McGarvey and Schendel suggest that the meaning of this finding is unclear and they suggest that more research on achievement orientation and social support are needed. I would suggest that the key need is an overall model of social effects that could allow an effective operationalization of modernization integrating individual, household, and community variables.

Janes (Janes and Pawson 1986; Janes 1990) undertook a study of Samoan migrants living in the San Francisco Bay Area, employing a social psychological stress—adaptation model. Most importantly, Janes embedded his model in the Samoan ethnographic context, by conducting a traditional anthropological ethnographic survey as the first phase of his research. The understanding gained from this phase allowed him to hypothesize that working women would experience more psychosocial stress due to the role conflicts of maintaining a household and working outside the home while Samoan men would remain occupied with enhancing their status. However, in the migrant context, they would have to do so by the acquisition of status items such as a house, car, and furniture.

Because of these differences in orientation between Samoan men and women, Janes (1990) reasoned that they would experience the stresses of migration and social change differently. He went on to hypothesize that men would be most affected by stressors in the social status arena while women should be most affected by difficulties occurring in the Samoan household or extended family. He devised two separate scales of status, one for economic status and another for leadership status, and calculated the difference between the two scales to obtain a measure of social inconsistency which he defines as '... the tension between individual and household needs and social status demands and aspirations . . .' (Janes 1990, p. 231). His measure of social inconsistency was significantly associated with blood pressure for men but not women, such that higher levels of inconsistency covaried with higher blood pressures.

Conversely, higher levels of family stressors were associated with higher blood pressures of women, but not men (Janes 1990).

In 1989 and 1992, I was involved in two investigations using a status incongruence model in an attempt to explain the effects of modernization on the blood pressure of Samoans. The model adopted for these studies is based on the life-style incongruity model developed by Dressler (1982, 1991) to explain psychosocial stress and health outcomes in modern and developing societies. This method has the attractive virtue of being derived directly from social theory. The variables within the life-style incongruity model are defined by Weber's model of social inequality (Weber 1946). In particular, Weber's 'class' refers to the individual's market situation or the ability to generate economic resources. Class, therefore, is a function of occupation, and can be estimated from an evaluation of occupation within the hierarchy of occupations in the group under study. 'Status' refers to the prestige publicly claimed by the individual, and varies with life-style. This life-style is defined by the consumption of goods, and hence can be measured by an inventory of material culture. Coming back to the adaptation paradigm, stress occurs when class and status or economic resources and life-style are inconsistent, i.e. when an individual projects a life-style which is either above or below his occupational class. In a modernizing context, this is most likely to occur when an individual attempts to project a life-style through the consumption of material culture and media that is beyond his (and his family's) ability to sustain economically.

A second advantage of this model is that it has been operationalized and tested with regard to cardiovascular risk in many social contexts, including developing countries (Dressler 1982, 1984, 1988, 1991; Dressler *et al.* 1987a,b, in press; Dressler and Bindon in press). The fact that the life-style measurement is based on an inventory of household material culture and media behaviour is theoretically satisfying. In language contact between groups, the most frequently borrowed words tend to be those denoting material culture—indicating the importance of the spread of new items. Operationally, this model bridges two analytic levels: the individual and the household. The outcome or dependent variables are measured on the individual, as are covariates such as sex and age, while material life-style is measured on the household in which the individual resides. The economic resources can be measured on either the individual or household level, depending on the cultural context, although conceptually, it makes more sense to assess household resources, especially in the case of Samoans.

In 1989, Crews and I conducted a survey that used the life-style incongruity model to study blood pressure effects in a small group of men living in American Samoa (Bindon *et al.* 1991). This was my fourth trip to American Samoa over 13 years, and I was finally beginning to gain an appreciation of Samoan culture and history. I felt comfortable enough with American Samoa and life-styles there to attempt to provide the cultural context for the survey instruments. Our sample consisted of 30 Samoan men between the ages of 43 and 71 years, who had been measured by me previously in 1976. Some key characteristics of these men are presented in Table 8.3.

**Table 8.3** Characteristics of Samoan men in 1989 American Samoa survey ( $n = 30$ )

Variable	Mean	SD
Age (years)	53.9	6.8
Weight (kg)	94.6	19.0
Stature (cm)	169.2	5.8
Body mass index (kg/m <sup>2</sup> )	33.0	5.9
Triceps skinfold (mm)	16.5	7.2
Subscapular skinfold (mm)	35.0	13.3
Systolic blood pressure (mmHg)	144.0	21.9
Diastolic blood pressure (mmHg)	90.8	13.3

In addition, a household occupational class was devised based on the occupation of the (male) head of household, his spouse (all but two were married), and any other wage earners in the house. This information was combined to provide an estimate of the economic resources available to the subject. A material style of life (MSL) interview was administered, and an MSL index was derived consisting of 19 items, having a high reliability as assessed by Cronbach's alpha = 0.81. Table 8.4 presents the items included in the MSL index. Many of the items in the scale were direct translations of attempts to claim prestige according to American middle class standards of consumption of goods.

**Table 8.4** Items included in 1989 survey of material style of life

Is the house European style?	Does the family own a(n):
Is there more than one room in the house?	Electric or gas stove?
Is there a linoleum or tile floor covering?	Refrigerator?
Is the house well kept and neat?	Freezer?
Is there indoor plumbing?	Stereo?
In the last year did the subject visit:	Television?
Western Samoa?	Video cassette recorder?
Hawaii?	Ghetto blaster?
The US mainland?	Couch?
Does the family own a(n):	Carpet?
Truck?	Rugs?

Items score 1 for yes, 0 for no.

Both the household occupational class and the MSL were standardized to a mean of 50 and a standard deviation of 10. An aggregate term summing occupational class and MSL was constructed as a traditional indicator of socio-economic status. The life-style incongruity (LSI) term was created by subtracting the occupational variable from MSL. Thus, positive values indicate MSL exceeding occupational class—hence stressful incongruity.

Table 8.5 presents the standardized regression coefficients from a multiple

regression of blood pressure with age and triceps skinfold as covariates, and socio-economic status (aggregate term), LSI, and the age by LSI interaction term. Forced entry of variables was used, with age and triceps skinfold entered first, then socio-economic status, then life-style incongruity, and finally the interaction term. Both regressions produced highly significant solutions, with adjusted multiple  $R^2$  values of 0.36 for systolic and 0.47 for diastolic blood pressure. In each analysis, the only significant associations were for triceps skinfold and the age by LSI interaction—in both cases the interaction was the single best predictor of blood pressure.

**Table 8.5** Standardized regression coefficients for multiple regressions of systolic and diastolic blood pressure on life-style, age, and skinfold variables

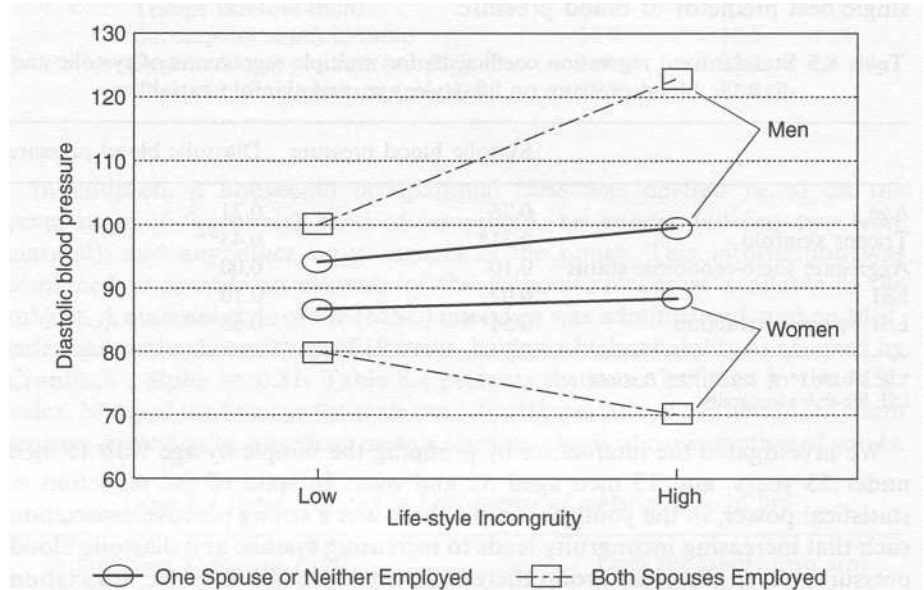
	Systolic blood pressure	Diastolic blood pressure
Age	0.26	0.21
Triceps skinfold	0.31*	0.43**
Aggregate socio-economic status	0.10	0.00
LSI	0.02	-0.10
LSI by age interaction	-0.54**	-0.55***

\*  $P \leq 0.05$ ; \*\*  $P \leq 0.01$ ; \*\*\*  $P \leq 0.001$ . LSI, life-style incongruity.

We investigated the interaction by grouping the sample by age with 15 men under 55 years, and 15 men aged 55 and over. In spite of the reduction in statistical power, in the younger sample there was a strong positive association such that increasing incongruity leads to increasing systolic and diastolic blood pressure, but in the older group there is an even stronger negative association with increasing incongruity leading to lower blood pressures. This examination of the interaction term emphasizes the importance of understanding the cultural patterns of context through which stress is experienced.

The rapid economic improvement that took place in American Samoa during the 1960s is possibly involved in producing the significant age by incongruity interaction term. Men who had entered the work force and were already established on their career track by the time conditions improved (men 55 years or older) were not affected by the stress of modernizing life-styles in the same way as are men who were entering the work force just as economic opportunities were opening up. Prior to the late 1960s, there were relatively few jobs available in American Samoa, and very limited opportunities for upward mobility. For the older men in our sample, prestige probably has a much more traditional Samoan perspective, in which status was not determined by possessions as much as by kin-ties, hard work, and age. Starting in the 1960s, modern life-style accoutrements became more important, and many Samoan men striving to enhance their prestige with limited occupational opportunities were subjected to tension created by the attempt to claim a higher status than they could sustain.

These findings were extended in a larger survey conducted in American Samoa in 1992, which examined LSI effects on blood pressure of both men and women, over a larger age range (Bindon *et al.* 1994). This survey also included more information about the household, as it is such an essential structure in the individual's interaction with the modernizing setting. A sample of 72 men and 68 women were surveyed in American Samoa. This survey found differential responses to LSI by gender, and depending on whether or not both spouses were engaged in accumulating the household income, as indicated in Fig. 8.3.



**Fig. 8.3.** Three-way interaction effect of life-style incongruity by number of spouses working by gender on diastolic blood pressure.

These results further emphasize the importance of the household as a contextual modifier of gender differences. The household is the centre of production and organization in Samoan life, and as such, it orders the division of labour. Husbands exercise primary authority over household production, while remaining conscious that their prestige within the community depends to a great deal upon how their household is perceived by other families. Conversely, Samoan women, as Janes (1990) demonstrated, are primarily concerned with household and family affairs. Their well-being is conditioned by their sense of household well-being, and it is likely that a woman who is working and feels that she is contributing to the betterment of her family experiences less stress with modernization than does the non-working wife.

These studies indicate some of the possibilities for combining ethnographically salient variables from the individual and household levels. The next step is to incorporate a community level variable to partial out variability from village

to village or between American Samoa and Hawaii. Through such models we will eventually gain a better understanding of the social processes that are affecting the biological variables that we wish to measure. By constructing culturally sensitive models of social support and assessing qualitative and quantitative components of social support, we can move into the next phase of assessing adaptation in Samoa. After substantial demonstration of the limits of adaptability as expressed through obesity and obesity-related conditions, understanding social support as an ameliorating agent for the psychosocial effects of modernization will provide an example of behavioural adaptation to a behaviourally mediated stress.

## **Assessments**

I would now like to offer a few considerations on what I deem to be some of the difficulties of previous research on Samoans, and some thoughts on remedies for future human adaptability research whenever behaviour is modelled as one of the primary variables.

### *Overpowering a research design*

In my discussion of the preliminary community level surveys, I took pains to point out the sampling problems that we encountered. Unlike most survey work, our problems did not have to do with too few subjects. On the contrary, much of the early work of the SSP was vastly oversampled. I was one of the worst offenders, helping to create the excess of about 1500 individuals (based on the power considerations outlined in Table 8.2) who were surveyed in American Samoa in 1976. As pleased as I was at the time to get such a substantial sample size, a little reflection would have reminded me to let my hypotheses drive my sampling. With the number of individuals measured, statistically significant differences at the community level were virtually guaranteed. However, the magnitude of difference in sample means that the produced statistical significance was frequently too small to lend itself to useful biocultural interpretation. Perhaps more importantly, none of the early samples were drawn with care for consideration of randomness or generalizability. Fortunately, the samples were generally reflective of the populations from which they were drawn in terms of education and occupation, but the fundamental validity of the statistical models was threatened by the use of opportunistic sampling.

Much smaller and more carefully constructed samples could have been used if the analytic models had been carefully specified and care taken to predict sample size requirements from the vast amount of both biological and social data that were available to predict the variables needed to estimate effect size (Lipsey 1990). Today, I would be happy to have a much smaller sample of individuals recruited with care to be representative of age, gender, and community differences that are ethnographically salient and methodologically valid.

In establishing such a sample, a model to test the interactions between community, household, and individual level influences must be specified. As a starting point, Dressler's model of LSI would serve. Future work should look to such a powerful design without cutting down on the time and effort spent on measuring social variables, and avoid overpowering a weak research design.

### *Problematic problem-oriented sampling*

The problem-oriented studies in the SSP pose a different problem because they tended to use highly selected samples of limited age range, single gender, and uncertain community affinity. By truncating the samples on age, with few subjects over the age of 30 included in these studies, one of the potentially most interesting aspects of modernization is overlooked. Namely, how has the process of modernization affected those whose developmental years were spent in a more traditional setting? There are sound ethnographic reasons to expect significant age effects on stress-related health variables because of the changes that have taken place with modernization of attitudes about family and veneration of elders. Similarly, the decrease in household size that has occurred over the last several decades has had the effect of diminishing the kin social support resources available to individuals who grew up in a system where family was the first line of defence in difficult times. As demonstrated by Janes (1990), this could have severe consequences especially for Samoan women.

Limiting many of the samples to young men further impedes our understanding of the modernization process, as we have strong expectations that males and females will be affected differentially. In any traditional setting with a strong gender-based division of labour this should be true. In Samoa, heavy agricultural work is done predominantly by males. Men clear the bush where the taro gardens are planted. It is also primarily men's work to carry the cuttings from harvested taro that are used to plant the new garden. Men will go to the gardens to harvest taro, bananas, breadfruit, and coconuts. Men and boys scrape the breadfruit and taro, and peel the green bananas. They grate the meat from ripe coconuts and then squeeze the gratings to make coconut cream. Building the rock oven (*umu*) and cooking the food is also the task of the untitled men. Men do most fishing, both within the reef and out to sea. The small dugout canoes (*paopao*) as well as the larger ocean-going bonito-canoes (*va'aalo*) require energetic rowing. If fishing is to be done within the reef, extensive swimming and diving is frequently necessary. In all of these activities, the males are interacting strongly with both kinsmen, but also with age-mates from other families. There is a well-defined hierarchy of familial importance, based on the chiefly title or *matai* system in Samoa. All of these relationships are clear-cut, and informal sanctions serve to keep behaviour generally within prescribed limits.

The traditional role of Samoan women includes gathering nearshore marine resources. Women help in the weeding and harvesting of the gardens, but the success of the garden is said to depend on the hard work of the men. Women

also gather firewood, and collecting banana or breadfruit leaves to cover the rock oven. They are responsible for child-care and house cleaning, although in Samoa, the older children play an important part in both child-care and housekeeping. Women also engage in crafts activities such as manufacture of woven mats and bark cloth. A Samoan woman's sphere of interaction is primarily defined by her household. Her ability to run a neat, efficient household reflects not only on her, but also on her husband.

These descriptions are valid for the traditional communities in Western Samoa today, as noted by Schendel (1989) and Pearson (1989). Schendel found that rural men spent about 15 hours per week farming, and another 3–5 hours fishing. An additional 8–10 hours per week were spent on domestic tasks, especially food preparation. Women in rural villages spent 3–5 hours per week on farming and fishing combined, with most of their time consumed in domestic tasks (nearly 20 hours per week), and crafts activities (about 15 hours per week). Pearson noted the differences in household interaction between males and females, with Samoan men spending significantly less time in the household context than the Samoan women (50% versus 75%), and the men spend significantly less time interacting with household members (12% versus 33%).

Not just the traditional division of labour and cultural expectations, but modernization also has gender-related concomitants. Men were the first to be incorporated into the wage earning force in Samoa, and so they were the first segment of the household to be taken out of the family labour pool. The jobs available to men early in the process of development tend to be labour-intensive. So while they are producing cash instead of food, their level of physical activity is little changed. While weight changes for males in this initial phase may be minimal (Bindon 1995), social changes, such as disruption of the village hierarchy with income replacing the traditional prestige accorded to different families, may be creating substantial psychosocial stress for men.

On the other hand, the early phases of development are conducive to a reduction in activity levels among women. When male labour is taken out of the household labour pool, changes in food gathering and preparation are necessary. Some of the first imported items incorporated into the Samoan diet were flour, tinned meat, and tinned fish—taking the place of the garden staples harvested by men and the marine resources that were previously gathered by the women. In addition, food preparation shifted from the rock oven that the men make to kerosene stoves—more appropriate for women's use. That also freed women from having to gather firewood and leaves for the rock oven daily. These changes in sex roles are further reinforced by Samoan food ideology. Samoan garden staples are traditionally prepared and cooked by men, whereas imported foods are appropriate for women to prepare. This distinction is related to the orientation of the Samoan village, with the bush (*'i uta*) and its starchy products (*mea a'ano*) being in the realm of men, while light protein foods and imported goods (*mea lelei*, literally good things) come from the sea (*'i tai*), and are appropriate for females to prepare. There is much slippage of these divisions in practice, but it provides a rationale in traditional Samoan terms in favour of

shifting from the traditional to imported foods as female labour was still available when Samoan men started working outside the household. Under these conditions, more calorically dense food becomes available in the household at the same time that less physical activity is required of females. In addition, women retain their household orientation, and social interactions are primarily with kin.

Schendel's (1989) survey of the time expenditure of Samoan men and women in urban Western Samoa bears out the description above. She found that the men spent less than 10 hours per week on farming and fishing combined, and most of their time (20–25 hours per week on average) was spent in wage-earning jobs. Domestic time was reduced to about 5 hours per week, and was primarily involved in preparation of the Sunday feast. Urban Samoan women spent about 2 hours per week on farming and fishing activities, and about 20 hours per week in domestic tasks. They averaged about 12 hours per week on wage jobs, and about 5 hours per week on crafts activities.

As development progresses further, education and employment opportunities open up and the Samoans move from labour-intensive to knowledge-intensive jobs. As this happens, both men and women tend to adopt sedentary life-styles. After the initial changes of development, little alteration of female activity patterns can be anticipated until they enter the wage pool in large numbers. Even when female employment accelerates, women tend to take low-activity jobs, and so there is no appreciable decline in obesity levels with additional modernization among Polynesian women. On the other hand, as more men take advantage of education, more of them end up in low-activity jobs.

While Samoan men in more modern settings still pursue traditional positions of prestige within the *matai* system, success in these pursuits depends increasingly on the ability to meet Euro-American ideals of position. Access to resources to bolster claims of prestige tends to be in short supply, creating tension in upwardly mobile males. Employment of wives in Samoan families may help Samoan men to attain higher status, while at the same time eroding prestige within the traditional system, as the spouse has less time to see to household responsibilities. Employment for women takes them out of the traditional security of the household, but it also exposes them to a large number of non-kin, and potentially enlarges the social support network. In addition, if the supplementary economic resources improves the woman's view of household well-being, her employment may help to ease the stress of modernizing.

Community sampling in the problem-oriented studies suffers from many of the same problems experienced in the preliminary surveys. Each village in both American and Western Samoa has a very individual identity with a unique history and idiosyncratic social context. Urban areas such as Apia in Western Samoa, and Pago Pago and Fagatogo in American Samoa are actually aggregations of several smaller villages, many of which retain their former identities. No sampling or analytic techniques have yet been employed to examine or exploit the intervillage differences. Finally, the community studies

that have been done have not been analysed in a way to disaggregate individual, household, and community level effects of modernization.

In conclusion, I think that research on Samoan populations is finally at a stage where we can begin to answer some of the questions we had about social change and health outcomes when the project was started. In addition to the careful outcome measures and the exploratory models of behavioural variables, we are at a point where we can begin to analyse adaptations to the shift in adaptive landscape that has occurred over the past several decades for Samoans. I look forward to ever more fruitful studies as our research designs become more biocultural and better integrate the different levels of social organization. Perhaps someday soon, in part because of the SSP, studies of stress and adaptation based on culture change will rival for elegance those based on altitude, climate, and nutrition.

## References

- Baker, P. T. (1982). Human population biology: A viable transdisciplinary science. *Human Biology*, **54**, 203-220.
- Baker, P. T. (1984a). The adaptive limits of human populations. *Man*, **19**, 1-14.
- Baker, P. T. (1984b). Migrations, genetics, and the degenerative diseases of South Pacific Islanders. In *Migration and mobility* (ed. A. J. Boyce), pp. 209-39. Taylor & Francis, London.
- Baker, P. T. (1986). Rationale and research design. In *The changing Samoans: behavior and health in transition* (ed. P. T. Baker, J. M. Hanna, and T. S. Baker), pp. 3-18. Oxford University Press, New York.
- Bindon, J. R. (1982). Breadfruit, banana, beef, and beer: Modernization of the Samoan diet. *Ecology of Food And Nutrition*, **12**, 49-60.
- Bindon, J. R. (1984a). An evaluation of the diet of three groups of Samoan adults: Modernization and dietary adequacy. *Ecology of Food and Nutrition*, **14**, 105-15.
- Bindon, J. R. (1984b). Body build and composition of Samoan children: Associations with infant feeding patterns and infant weight-for-length status. *American Journal of Physical Anthropology*, **63**, 379-88.
- Bindon, J. R. (1988). Taro or rice, plantation or market: dietary choice in American Samoa. *Food and Foodways*, **3**, 59-78.
- Bindon, J. R. (1995). Polynesian responses to modernization: Overweight and obesity in the South Pacific. In *Social aspects of obesity* (ed. I. de Garine and N. J. Pollock), pp. 227-51. Gordon and Breach, London.
- Bindon, J. R. and Baker, P. T. (1985). Modernization, migration, and obesity among Samoan adults. *Annals of Human Biology*, **12**, 67-76.
- Bindon, J. R. and Baker, P. T. (in press). Bergmann's rule and the thrifty genotype. *American Journal of Physical Anthropology*.
- Bindon, J. R. and Zansky, S. M. (1986a). Growth and morphology. In *The changing Samoans: behavior and health in transition*. (ed. P. T. Baker, J. M. Hanna, and T. S. Baker), pp. 222-53. Oxford University Press, New York.
- Bindon, J. R. and Zansky, S. M. (1986b). Patterns of growth in height and weight among three groups of Samoan pre-adolescents. *Annals of Human Biology*, **13**, 171-8.
- Bindon, J. R., Crews, D. E., and Dressler, W. W. (1991). Life style, modernization, and adaptation among Samoans. *Collegium Anthropologicum*, **15**, 101-10.

- Bindon, J. R., Knight, A. L., Dressler, W. W., and Crews, D. E. (1994). Stress, gender, and household employment influences on blood pressure of Samoan adults. *American Journal of Human Biology*, **6**, 116.
- Booth, R. (1985). The two Samoas: Still coming of age. *National Geographic*, **168**, 452-73.
- Crews, D. E., Kamboh, M. I., Bindon, J. R., and Ferrell, R. E. (1991). Genetic studies of human apolipoproteins XVII. Population genetics of apolipoprotein polymorphisms in American Samoa. *American Journal of Physical Anthropology*, **84**, 165-70.
- Curry, S. J., Wagner, E. H., Cheadle, A., Diehr, P., Koepsell, T., Psaty, B., and McBride, C. (1993). Assessment of community-level influences on individuals' attitudes about cigarette smoking, alcohol use, and consumption of dietary fat. *American Journal of Preventive Medicine*, **9**, 78-84.
- DeFronzo, R. A. (1982). Insulin secretion, insulin resistance, and obesity. *International Journal of Obesity*, **6** (Suppl. 1), 73-82.
- DeFronzo, R. A. and Ferrannini, E. (1982). The pathogenesis of non-insulin-dependent diabetes: an update. *Medicine*, **61**, 125-40.
- Diehr, P., Koepsell, T., Cheadle, A., Psaty, B., Wagner, E. H., and Curry, S. J. (1993). Do communities differ in health behaviors? *Journal of Clinical Epidemiology*, **46**, 1141-9.
- Dressler, W. W. (1982). *Hypertension and culture change: acculturation and disease in the West Indies*. Redgrave, South Salem.
- Dressler, W. W. (1984). Hypertension and culture change in the Caribbean. In *Health care in the Caribbean and Central America*, Studies in Third World Societies, Publication No. 30., (ed. F. McGlyn), pp. 69-93, College of William and Mary, Williamsburg.
- Dressler, W. W. (1988). Social consistency and psychological distress. *Journal of Health and Social Behavior*, **29**, 79-91.
- Dressler, W. W. (1989). Type A behavior and the social production of cardiovascular disease. *Journal of Nervous and Mental Disease*, **177**, 181-90.
- Dressler, W. W. (1991). *Stress and adaptation in the context of culture: depression in a southern Black community*. SUNY Press, Albany.
- Dressler, W. W. (1992). Culture, stress, and depressive symptoms: building and testing a model in a specific setting. In *Anthropological research: process and application* (ed. J. J. Poggie, Jr., B. R. DeWalt, and W. W. Dressler), pp. 19-33. SUNY Press, Albany.
- Dressler, W. W. (1995). Modeling biocultural interactions: examples from studies of stress and cardiovascular disease. *Yearbook of Physical Anthropology*, **38**, 27-56.
- Dressler, W. W. and Bindon, J. R. (in press). Social status, social context and arterial blood pressure. *American Journal of Physical Anthropology*.
- Dressler, W. W., Dos Santos, J. E., Gallagher, P. N., Jr., and Viteri, F. E. (1987a). Arterial blood pressure and modernization in Brazil. *American Anthropologist*, **89**, 398-409.
- Dressler, W. W., Mata, A., Chavez, A., and Viteri, F. (1987b). Arterial blood pressure and individual modernization in a Mexican community. *Social Science and Medicine*, **24**, 679-87.
- Dressler, W. W., J. R. Bindon, and M. J. Gilliland. (in press). Status incongruence and plasma glucose among the Mississippi Choctaw. *Medical Anthropology*.
- Green, R. C. (1979). Lapita. In *The prehistory of Polynesia* (ed. J. D. Jennings), pp. 27-60. Harvard University Press, Cambridge, MA.
- Greksa, L. P., Pelletier, D. L., and Gage, T. B. (1986). Work in contemporary and traditional Samoa. In *The changing Samoans: behavior and health in transition* (ed. P. T. Baker, J. M. Hanna, and T. S. Baker), pp. 297-326. Oxford University Press, New York.

- Hanna, J. M., James, G. D., and Martz, J. M. (1986). Hormonal measures of stress. In *The changing Samoans: behavior and health in transition* (ed. P. T. Baker, J. M. Hanna, and T. S. Baker), pp. 203-21. Oxford University Press, New York.
- Henry, J. P. and Cassel, J. C. (1969). Psychosocial factors in essential hypertension: Recent epidemiological and animal experimental evidence. *American Journal of Epidemiology*, **90**, 171-200.
- Herd, J. A. (1978). Psychological correlates of coronary-prone behavior. In *Coronary-prone behavior*, (ed. T. M. Dembroski, S. Weiss, J. Shields, S. Haynes, and M. Feinleib), pp. 201-27. Springer-Verlag, New York.
- Hornick, C. A. (1979). Heart disease in a migrating population. Unpublished doctoral dissertation, The University of Hawaii, Honolulu.
- James, G. D., Jenner, D. A., Harrison, G. A., and Baker, P. T. (1985). Differences in catecholamine excretion rates, blood pressure and lifestyle among young Western Samoan men. *Human Biology*, **57**, 635-47.
- James, G. D., Baker, P. T., Jenner, D. A., and Harrison, G. A. (1987). Variation in lifestyle characteristics and catecholamine excretion rates among young Western Samoan men. *Social Science and Medicine*, **25**, 981-6.
- Janes, C. R. (1990). Migration, changing gender roles and stress: The Samoan case. *Medical Anthropology*, **12**, 217-48.
- Janes, C. R. and Pawson, I. G. (1986). Migration and biocultural adaptation: Samoans in California. *Social Science and Medicine*, **22**, 821-34.
- Jenner, D. A., Reynolds, V., and Harrison, G. A. (1980). Catecholamine excretion rates and occupation. *Ergonomics*, **23**, 237-46.
- Kirk, R. L., Serjeantson, S. W., King, M., and Zimmet, P. (1985). The genetic epidemiology of diabetes mellitus. In *Diseases of complex etiology in small populations* (ed. R. Chakraborty and E. Szathmary), pp. 121-44. Alan R. Liss, New York.
- Krotkiewski, M., Lonroth, P., Mandroukas, K., Wroblewski, Z., Rebuffe-Scrive, M., Holm, G., et al. (1985). The effects of physical training on insulin secretion and effectiveness and on glucose metabolism in obesity and type 2 (non-insulin-dependent) diabetes mellitus. *Diabetologia*, **28**, 881-90.
- Levy, M. J., Jr. (1966). *Modernization and the structure of societies: a setting for the study of international affairs*. Princeton University Press, Princeton, New Jersey.
- Lewthwaite, G. R., Mainzer, C., and Holland, P. J. (1973). From Polynesia to California: Samoan migration and its sequel. *Journal of Pacific History*, **8**: 133-57.
- Lipsey, M. S. (1990). *Design sensitivity: statistical Power for Experimental Research*. Sage Publications, Newbury Park, California.
- Little, M. A. and Haas, J. D. (1989). Introduction: Human population biology and the concept of Transdisciplinarity. In *Human population biology: a transdisciplinary science* (ed. M. A. Little and J. D. Haas), pp. 3-12. Oxford University Press, New York.
- Lukaski, H. C. (1977). Some observations on the coronary risk status of male Samoan migrants on Oahu, Hawaii. Unpublished Master's thesis. The Pennsylvania State University, University Park.
- Malkoff, S. B., Muldoon, M. F., Ziegler, Z. R., and Manuck, S. B. (1993). Blood platelet responsivity to acute mental stress. *Psychosomatic Medicine*, **55**, 477-82.
- McArthur, N. A. (1967). *Island populations of the Pacific*. Australian National University Press, Canberra.
- McGarvey, S. T. and Schendel, D. E. (1986). Blood pressure of Samoans. In *The changing Samoans: behavior and health in transition* (ed. P. T. Baker, J. M. Hanna, and T. S. Baker), pp. 351-93. Oxford University Press, New York.
- Minuk, H. L., Vranic, M., Marliss, E. B., Hanna, A. K., Arblisser, A. M., and Zinman,

- A. M. (1981). Glucoregulatory and metabolic response to exercise in obese noninsulin-dependent diabetes. *American Journal of Physiology*, **240**, 458-64.
- Neel, J. V. (1962). Diabetes mellitus: a 'thrifty' genotype rendered detrimental by 'progress'? *American Journal of Human Genetics*, **14**, 53-62.
- Olefsky, J. M., Kolterman, O. G., and Scarlett, J. A. (1982). Insulin action and resistance in obesity and noninsulin-dependent type II diabetes mellitus. *American Journal of Physiology*, **243**, E15-30.
- Parsons, C. J. (1982). Samoan migrants and nonmigrants: a morphological and genetic comparison. Unpublished Ph.D. dissertation, Department of Anthropology, The Pennsylvania State University.
- Pawson, I. G. (1986). The morphological characteristics of Samoan adults. In *The changing Samoans: behavior and health in transition* (ed. P. T. Baker, J. M. Hanna, and T. S. Baker), pp. 254-74. Oxford University Press, New York.
- Pearson, J. D. (1989). *Urinary catecholamine excretion, daily activities, and stress in rural Western Samoa, American Samoa, and urban Honolulu*. Unpublished Ph.D. dissertation. Pennsylvania State University, University Park.
- Pearson, J. D., James, G. D., and Brown, D. E. (1993). Stress and changing lifestyles in the Pacific: physiological stress responses of Samoans in rural and urban settings. *American Journal of Human Biology*, **5**, 49-60.
- Pelletier, D. L. (1984). Diet, activity and cardiovascular disease risk factors in Western Samoan men. Unpublished Ph.D. dissertation. Department of Anthropology, Pennsylvania State University.
- Pelletier, D. L. (1987). The relationship of energy intake and expenditure to body fatness in Western Samoan men. *Ecology of Food and Nutrition*, **19**, 185-99.
- Pelletier, D. L. and Hornick, C. A. (1986). Blood lipid studies. In *The changing Samoans: behavior and health in transition* (ed. P. T. Baker, J. M. Hanna, and T. S. Baker), pp. 327-50. Oxford University Press, New York.
- Pike, R. L. and Brown, M. L. (1975). *Nutrition: an integrated approach*. New York: John Wiley & Sons.
- Prior, I. A. M. (1977). *Nutritional problems in Pacific Islanders*. Nutrition Society of New Zealand, Auckland.
- Reynolds, V., Jenner, D. A., Palmer, C., and Harrison, G. A. (1981). Catecholamine excretion rates in relation to life-styles in the male population of Otmoor, Oxfordshire. *Annals of Human Biology*, **8**, 197-209.
- Schendel, D. E. (1988). Daily activity, energy intake and body composition among Western Samoans. *American Journal of Physical Anthropology*, **75**, 267.
- Schendel, D. E. (1989). Sex differences in factors associated with body fatness in Western Samoa. Unpublished Ph.D. dissertation. Department of Anthropology, Pennsylvania State University.
- Smith, T. (1967). Sociocultural incongruity and change: A review of empirical findings. In *Social stress and cardiovascular disease* (ed. S. Syme and L. Reeder), pp. 23-39. Milbank Memorial Fund Quarterly, New York.
- Weber, M. (1946). *Essays in sociology*. (ed. and trans. H. Girth and C. W. Mills). Oxford University Press, New York.
- Zimmet, P. (1982). Type 2 (non-insulin-dependent) diabetes: an epidemiological overview. *Diabetologia*, **22**, 399-419.