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Craniometric Variation in Micronesia and the Pacific: A Multivariate Study

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Abstract—Multivariate statistical analyses of craniometric data from Micronesia, circum-Micronesian Pacific, Southeast Asia, and East Asia, suggest an east-west division within Micronesia. Other comparisons indicate, however, that while there may have been closer ties between Western Micronesian and Southeast or East Asian populations on the one hand and affinities between Eastern Micronesian and Polynesian populations on the other, there is a basic continuity within all the Micronesian peoples. The analysis does not support the belief that either the Micronesian or the Polynesian populations were derived from Melanesian populations.

Introduction

Studies of cranial variation within the geographical limits of Micronesia have been largely anecdotal. This situation is due, in part, to the unavailability of sufficiently large cranial series from the region. Earlier skeletal studies, mostly by German and Japanese researchers, typically utilized small collections of skeletons and skulls which were collected in the Mariana Islands (e.g. Arai 1941; Hasebe 1928, Krause 1881, Schlaginhaufen 1906, Virchow 1881). The present situation has changed little and, with the exception of Guam and to a lesser extent the Northern Marianas, good series of crania from Micronesia are still lacking. Furthermore, the meagre collections that do exist are in museums located in Europe, the United States, Australia and Japan [see Pietrusewsky (1986) for a summary of the Pacific crania preserved in museums]. Recent archaeological activities in Micronesia have further failed to provide very extensive samples of crania for such an assessment (see e.g., Hanson unpub., Katayama 1985, Pietrusewsky & Batista 1980, Pietrusewsky & Douglas unpub., Pietrusewsky unpub., Underwood unpub., Webb unpub.). It is therefore not surprising that a comprehensive study of Micronesian craniology is unavailable at present.

The purpose of the present paper is to assemble, for the first time, a representative sampling of crania from Micronesia located in museums in Europe, Australia and Hawaii. Smaller series of Micronesian crania found in museums on the U.S. mainland and Japan are not represented. The paper examines one of the largest assemblages of complete or nearly complete male crania from Micronesia currently available. The main objective will be to assess, through the application of multivariate statistical procedures, the biological relationships of Micronesian crania and the probable origins of these populations through comparisons with crania from surrounding regions of the Pacific and mainland Asia.

Material and Methods

MICRONESIAN SERIES

The Micronesian material includes 137 substantially complete male crania from several major regions including the Marianas, Palau, central Carolines, eastern Micronesia (Gilbert and Marshall Is.) and Nauru. Comparable information was collected on female specimens but because of the smaller number of crania available, these data are not included in the present study. Using geography and culture as the primary sorting criteria, the material is divided into ten samples. The representativeness of these samples, the number of crania measured for each, the location of the specimens and other notes on the provenience of the material are presented in Table 1.

The material is primarily preserved in museums which acquired these specimens in the late 19th and early 20th centuries, usually as part of large scale collecting expeditions. Although no report was ever published, only the material from the Marianas preserved in the B. P. Bishop Museum in Honolulu has archaeological provenience (although this work was done well before the advent of modern archaeology). Attempts to locate additional Micronesian crania have been largely unsuccessful (see Pietrusewsky 1986). Except for Guam and Saipan, the sample sizes are uniformly small. Despite these shortcomings, the present sample, representing substantially complete crania, is the largest assembled to date.

CIRCUM-MICRONESIAN SAMPLES

The comparative data consist of 1406 male crania representing 28 samples from Polynesia, Melanesia, island and mainland Southeast Asia and East Asia. The samples, number of crania in each, location of material and other details of provenience are given in Table 2. All data were recorded by Pietrusewsky at various intervals between approximately 1975 and 1985. Like the Micronesian series, much of the comparative material was acquired by museums *ca.* 1900. Although exact temporal relationships are generally unknown, a great many of the specimens, given their early accession dates, approximate near-contemporary populations. In some instances the villages where the specimens were collected is known (e.g., the Sepik River material) but in others they are traceable only to an island or larger geographical unit. Age and sex determinations were made by visual inspection following standard forensic and osteological procedures.

CRANIAL MEASUREMENTS & CRANIOMETRIC METHODS

The names and source references for thirty-six standard cranial measurements recorded in each specimen are listed in Table 3. Only complete, or substantially complete, adult crania have been measured. Provided predetermined limits (for individuals as well as for variables) were not exceeded, missing measurements were replaced by regressed values obtained through stepwise regression analysis, based on each specimen's group, using the computer program PAM of the Biomedical Computer Program P-Series (Dixon & Brown 1979). In most instances, no more than three measurements per individual or variable were originally missing. Because the zygomatic arches are often incomplete, bizygomatic breadth (BIZYGOMB) was eliminated from the analysis.

Table 1. Samples of Micronesian Male Crania

Sample	No. Male Crania	Location of Specimens[1]	Comments
Guam (GUA)	51	BPB-46; PAR-5	Majority of specimens in the Bishop Museum were excavated by H.G. Hornbostel at Tumon Beach,Guam.
Northern Marianas			
Saipan (SAI)	23	BPB-2; PAR-21	Specimens in Paris collected by A.Y. Marche in 1883.
Tinian (TIN)	6	BPB-6	All specimens are from Taga, Tinian Is.
Marianas (MAR)	5	PAR-5	Three crania are from Pagan Is. and one is from Rota, Northern Marianas.
Western Carolines			
Palau (PAL)	13	BER-10; DRE-1; GOT-2	Specimens in Berlin were collected by J.S. Kubary on Palau (Kubary, 1885).
Yap (YAP)	1	FRE-1	The Yap and Palau samples were combined to form a single sample.
Central Carolines			
Truk (TRK)	6	SYD-1; GOT-3; PAR-2	Göttingen specimens collected during Südsee Expedition in 1910; specimens in Paris collected by Pinart in 1878.
Eastern Carolines			
Ponape (PON)	11	DRE-9; PAR-2	Material in Dresden collected by Brocker in 1885/86.
Eastern Micronesia			
Nauru (NAR)	7	SYD-1; FRE-5; GOT-1	
Marshall (MRS)	7	BER-1; FRE-3; GOT-3	Most specimens are from Enewetak and Jaluit Atolls.
Gilbert (GIL)	7	PAR-7	Five crania were collected by Pinart in 1878 on Beru Is. (Cat. #6104-6108).

[1] See footnote at bottom of Table 2.

Table 2. Comparative Samples of Male Crania from the Pacific, Southeast Asia and East Asia

Sample (abbrev.)	No. Crania	Location of Collection	Provenience
Admiralty (ADR)	79	GOT-9;TUB-28; BAS-11; CHA-6 BRE-5; DRE-20	Crania are from Manus, Hermit and Kaniet Islands. All material in Dresden was collected by Captain Pöhl in 1888 from Hermit Is.
New Britain (NBR)	85	CHA-43; DRE-42	Crania in Dresden were collected by A. Baessler (1900). Collections in Berlin were made by R. Parkinson in 1911.
Sepik R. (SEP)	74	DRE-33; GOT-31; BRE-3; TUB-7	Crania in Dresden were collected by O. Schlaginhaufen in 1909; each specimen is documented by village.
Murrary R. (MRB)	85	MEL-46; CAN-39	Random sample of crania collected by G. Murray Black between 1929-40 along the Murray River, Southeast Australia.
W. Australia (WA)	47	PER-47	Material is from all parts of Western Australia.
Tasmania (TAS)	26	HOB-22; CHA-1 ADE-2; MEL-1	All but four specimens are from collections in Hobart.
Vanuatu (VAN)	84	BAS-84	Crania from Ambrym, Malo, Pentecost and Espirtu Santo. The majority are part of a collection made by F. Speiser in 1912.
Fiji (FIJ)	32	BPB-8; CHA-1; PAR-8; BRS-1; SYD-3; DRE-4; ADE-3; BER-1; FRE-3	A diverse sample from several islands of the Fijian group.
Tonga-Samoa (TGS)	12	BER-4; BPB-4; SYD-1; PAR-1; GOT-1; DRE-1	Approximately equal representation from Tonga and Samoa.
Tahiti (TAH)	33	PAR-33	Crania from Tahiti, Society Is.
Marquesas (MRQ)	51	PAR-49; LEP-1; GOT-1	Material from Fatu Hiva, Tahuata, Nuku Hiva and Hiva Oa, Marquesas.
New Zealand (NZ)	70	DRE-8; ADE-1; AIM-17; GOT-6; BRE-3; ZUR-8; PAR-27	Crania from various locations in the North and South Islands.
Easter Is. (EAS)	64	BER-5; DRE-9; PAR-43; SYD-7	Majority of crania in Paris were collected by Pinart in 1877 at Vaihu and La Perouse Bay on Easter Island.
Hawaii (HAW)	49	BPB-49	Prehistoric Hawaiian crania from Mokapu, Northeastern O'ahu.
Philippines (PHL)	28	BER-9; DRE-19	Crania from Luzon: Abra, Balango, Cgayan, Infanta, Ilocos Sur, Mountain Province and Tarlac Provinces.
Sulu (SUL)	38	PAR-37; LEP-1	Crania were collected by Montano-Rey circa 1900.

Table 2. (cont'd)

Sample (abbrev.)	No. Crania	Location of Collection	Provenience
S. Moluccas (SMO)	61	BER-6; DRE-7; FRE-48	Majority of crania are from Ceram and Amboina.
L. Sundas (LSU)	45	DRE-17; BER-6; BAS-5; LEP-1; CHA-1; PAR-6 GOT-2; ZUR-7	Crania from Bali, Flores, Sumba, Lomblen, Alor, Timor Wetar, Leti and Babar Islands.
Sumatra (SUM)	39	ZUR-25; LEP-4; DRE-5; PAR-3; BRE-1; BER-1	Material in Zurich is designated 'Battak'. Five crania are from Nias Is.
Java (JAV)	73	BLU-8; PAR-28; BER-2; CHA-9; DRE-2; LEP-24	A diverse sample from various parts of Java; exact location of many specimens is known.
Borneo (BOR)	35	FRE-4; PAR-13; DRE-6; BER-2; LEP-8; BRE-2	Crania from Borneo. Exact location given for many specimens.
Celebes (CEL)	41	BER-10; BAS-7; PAR-8; FRE-7; DRE-4; LEP-5	The exact location for many of these specimens is known.
Cambodia (CAM)	11	PAR-11	Crania from Cambodia.
Vietnam (VET)	30	PAR-30	Crania from Tonkin, Annam and Cochinchina.
Laos (LAO)	29	PAR-29	Material collected by Noel Barnard representing Kha tribes and other inhabitants of Laos.
Burma (BUR)	16	ZUR-16	
Hong Kong (HK)	104	HK-104	Exhumed recent burials examined at University of Hong Kong (Dept. of Applied Oral Anatomy) in 1983 and 1985.
Japan (JAP)	65	PAR-65	Majority of these specimens were collected by Steenackers in 1886 from Kobe, Hyogo Province, Honshu Is.

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[1] ADE = South Australian Museum, Adelaide
AIM = Auckland Institute and Museum, Auckland
BAS = Naturhistorisches Museum, Basel
BER = Museum f. Naturkunde, Berlin
BLU = Anatomisches Institut, Unversität Göttingen, Göttingen
BPB = B.P. Bishop Museum, Honolulu
BRE = Übersee Museum, Bremen
BRS = Department of Anatomy, Queensland University, Brisbane
CAN = Australian Institute of Anatomy, Canberra
CHA = Anatomisches Institut der Chairté, Humboldt Universität Berlin
DRE = Museum für Völkerkunde, Dresden
FRE = Institut f. Humangenetik u. Anthropologie, Universität Freiburg
GOT = Institut f. Anthropologie, Universität Göttingen, Göttingen
HOB = Tasmanian Museum & Art Gallery, Hobart
HK = University of Hong Kong, Hong Kong
LEP = Anatomisches Institut, Karl Marx Universität, Leipzig
MEL = Department of Anatomy, Melbourne University, Melbourne
PAR = Musée de l'Homme, Paris
PER = Western Australian Museum, Perth
SYD = The Australian Museum, Sydney
TUB = Institut f. Anthropologie u. Humangenetik, Universität Tübingen, Tübingen
ZUR = Anthropologisches Institut, Universität Zürich, Zürich

Table 3. List of Cranial Measurements Used in Present Study

Measurement Abbrev.	Cranial Measurement	Reference
MAXCRANL	Maximum cranial length	Martin's[1] No. 1
NASOCCIL	Nasio-occipital length	Martin's No. 1d
BASINASI	Basion-nasion	Martin's No. 5
BASIBREG	Basion-bregma	Martin's No. 17
MAXCRANB	Maximum cranial breadth	Martin's No. 8
MAXFRONB	Maximum frontal breadth	Martin's No. 10
MINFRONB	Minimum frontal breadth	Martin's No. 9
BISTEPHB	Bistephanic breadth	Howells'[2] STB
BIZYGOMB	Bizygomatic breadth	Martin's No. 45
BIAURICB	Biauricular breadth	Martin's No. 11b
MINCRANB	Minimum cranial breadth	Martin's No. 14
BIASTERI	Biasterionic	Martin's No. 12
BASIPROS	Basion-prosthion	Martin's No. 40
NASIPROS	Nasion-prosthion	Martin's No. 48
NASALHGT	Nasal height	Martin's No. 55
NASALBTH	Nasal breadth	Martin's No. 54
ORBHGTLF	Orbital height, left	Martin's No. 52
ORBBTHLF	Orbital breadth, left	Martin's No. 51a
BIJUGALB	Bijugal breadth	Martin's No. 45(1)
ALVEOLAL	Alveolar length	Martin's No. 60
ALEVOLAB	Alveolar breadth	Martin's No. 61
MASTOIDH	Mastoid height	Howells' MDL
MASTOIDW	Mastoid width	Howells' MDB
BIMAXILB	Bimaxillary breadth	Martin's No. 46
BIFRONTB	Bifrontal breadth	Martin's No. 43
BIORBITB	Biorbital breadth	Howells' EKB
INTERORB	Interorbital breadth	Martin's No. 49a
MALRLINF	Malar length, inferior	Howells' IML
MALRLMAX	Malar length, maximum	Howells' XML
CHEEKHGT	Cheek height	Martin's No. 48(4)
FORAMAGL	Foramen magnum length	Howells' FOL
NASIBGCR	Nasion-bregma chord	Martin's No. 29
BRGLMDCR	Bregma-lambda chord	Martin's No. 30
LAMOPISC	Lambda-opisthion chord	Martin's No. 31
BIMAXSUB	Bimaxillary subtense	Howells' SSS
NASFROSB	Nasio-frontal subtense	Howells' NAS

[1] Martin (1957)
[2] Howells (1973)

Stepwise discriminant function analysis was applied to the cranial measurements using the computer program BMDP7M (Dixon & Brown, 1979). Mahalanobis' Generalized Distance or d-squared (Mahalanobis 1936), which provides a quantative measure of distance between groups based on many variables, has been applied to the craniometric data analyzed by discriminant analysis (Rightmire 1972: 268). The unweighted pair-group clustering technique (Sneath & Sokal 1973), which uses arithmetic averages, was the algorithm selected for constructing the diagrams of relationship based on the d-squared results.

Multivariate procedures were applied to three separate sets of data. In the first, group relationships among the ten Micronesian samples were investigated using 35 cranial measurements. The Micronesian samples were then combined to form five composite samples. Finally, the ten Micronesian samples were compared with 28 circum-Micronesian cranial samples using 30 measurements. The results of each analysis are reported separately.

Results

PAN MICRONESIAN COMPARISONS

Multivariate procedures were first applied to 35 measurements recorded in ten Micronesian samples. The means and standard deviations of 36 cranial measurements for each of the samples are presented in Table 4. Stepwise discriminant function analysis was applied to these data. A ranking of these measurements, arranged according to F-values received in Step O of discriminant analysis, is presented in Table 5, and their ranking according to the F-values received in the final step of discriminant analysis is presented in Table 6. These rankings suggested that biauricular breadth, followed by basion-bregma height, alveolar length, nasion-prosthion and maximum frontal breadth, are the most important multivariate discriminators for the ten Micronesian samples.

Eigenvalues, the percentage of total dispersion, cumulative dispersion and level of significance for the first nine discriminant functions (canonical variables) are presented in Table 7. Howells (1972, 1973) provides an excellent explanation of the meaning of canonical analysis and discriminant function analysis. The mathematical meaning of these terms is given in Dixon and Brown (1979) and Cooley and Lohnes (1971). The first four functions (significant at $P < .01$) account for approximately 80 percent of the total discrimination.

Canonical coefficients for the 35 measurements for the first two functions, which account for more than 70 percent of the total dispersion, arranged in decreasing magnitude, are presented in Table 8. Interpreting the meaning of these functions from the coefficients of its scores with the original measurements indicates that nasion-prosthion (facial height) and bijugal breadth (mid-facial breadth) both figure prominently in producing the observed differentiation within Micronesia. Dimensions of the orbit, nasal aperture and hard palate heavily influence the first discriminant function.

Classification (Table 9) proceeded based on Mahalanobis' d-squared and the posterior probability scores for each case after the final step of the discriminant analysis. Perfect classification was observed for five of the ten samples. The poorest classification results were obtained for cases originally assigned to Saipan, with 6 of the 23 cases misclassified. Overall, however, the classification results are good.

Figure 1 is the plot of the group means on the first two discriminant functions. In this diagram the four samples from the Marianas form a cluster. Truk, the Gilberts and the Marshall Islands comprise a second cluster. Nauru and, to a greater extent, Palau and Ponape, occupy more peripheral positions in this representation.

Mahalanobis' Generalized Distance is next applied to the same data analyzed by discriminant function analysis. Figure 2 is the diagram of relationship based on a cluster analysis of the d-squared values. As was found in the discriminant function results, the four Marianas samples form a distinct cluster in this representation. Set off from these are samples drawn from eastern Micronesia (Gilberts & Marshalls) and Truk from the central Carolines. The Nauru sample is relatively independent of the latter. Finally, a weak association obtains between Ponape and Palau, one well-removed from all other groups in this diagram.

COMBINED MICRONESIAN SAMPLES

In an attempt to gain a more general impression of the biological relationships within Micronesia, several of the original ten samples were collapsed to form five samples:

Table 4

Means and Standard Deviations for 36 Measurements Recorded in Male Crania from Micronesia

	Gilbert N=7		Marshall N=7		Truk N=6	
Measurement	Mean	S.D.	Mean	S.D.	Mean	S.D.
MAXCRANL	176.3	6.1	180.0	4.2	180.8	5.8
NASOCCIL	175.4	6.2	177.0	3.5	177.5	4.4
BASINASI	101.9	4.1	102.6	3.6	102.8	4.2
BASIBREG	135.9	3.7	137.3	5.2	141.0	2.0
MAXCRANB	130.9	4.8	131.9	4.2	132.3	2.4
MAXFRONB	109.6	5.7	108.6	5.0	113.8	3.9
MINFRONB	92.0	4.8	93.6	3.9	95.8	3.5
BISTEPHB	105.0	6.4	104.6	5.5	110.7	3.7
BIZYGOMB	129.3	5.3	132.0	5.7	130.0	4.6
BIAURICB	117.3	3.9	120.9	3.3	120.3	4.8
MINCRANB	68.0	6.5	69.3	3.0	71.0	2.5
BIASTERI	107.3	8.2	105.9	4.9	106.2	2.6
BASIPROS	103.3	3.9	102.1	4.5	98.7	6.3
NASIPROS	72.0	5.1	67.9	4.0	70.3	4.3
NASALHGT	56.0	4.4	52.4	2.9	55.0	4.8
NASALBTH	25.1	2.7	24.3	2.6	25.0	2.1
ORBHGTLF	34.1	2.3	33.3	1.4	35.8	1.8
ORBBTHLF	42.0	1.3	41.7	1.1	42.5	2.6
BIJUGALB	114.1	4.1	113.3	4.8	112.3	5.8
ALVEOLAL	55.6	1.4	53.9	3.4	52.5	5.0
ALVEOLAB	62.3	3.4	64.7	3.1	60.0	3.7
MASTOIDH	27.6	3.3	30.1	1.8	29.3	3.3
MASTOIDW	19.7	2.4	20.7	1.8	22.8	3.2
BIMAXILB	98.0	3.9	99.4	4.2	96.2	4.1
BIFRONTB	103.7	4.8	104.4	3.1	104.5	4.5
BIORBITB	96.0	2.8	96.7	3.6	96.2	3.7
INTERORB	26.9	2.1	30.1	4.7	26.5	0.8
MALRLINF	36.6	2.4	36.6	3.8	34.8	2.6
MALRLMAX	51.7	1.6	55.7	2.2	53.3	2.7
CHEEKHGT	24.0	1.9	24.4	1.8	24.3	2.8
FORAMAGL	34.4	2.7	33.6	2.5	33.8	1.5
NASIBGCR	111.1	5.0	108.1	3.7	114.0	3.6
BRGLMDCR	111.6	6.8	112.6	4.3	114.7	4.8
LAMOPISC	96.6	2.4	96.9	3.0	95.8	3.9
BIMAXSUB	24.0	1.5	24.6	3.9	24.8	3.4
NASFROSB	17.7	3.9	18.1	2.5	17.5	1.4

	Ponape N=11		Nauru N=7		Palau N=14	
Measurement	Mean	S.D.	Mean	S.D.	Mean	S.D.
MAXCRANL	179.0	7.4	188.0	3.2	176.4	5.3
NASOCCIL	174.9	6.1	185.1	2.7	172.5	5.6
BASINASI	98.0	2.7	106.6	3.9	99.4	5.1
BASIBREG	132.0	5.9	140.1	5.8	134.7	4.6
MAXCRANB	127.1	6.3	135.4	4.6	135.1	4.2
MAXFRONB	108.5	5.1	115.0	3.4	115.3	4.0
MINFRONB	93.5	6.1	100.0	2.9	96.1	4.7
BISTEPHB	102.2	7.5	111.3	4.1	109.7	4.9
BIZYGOMB	133.3	6.1	134.4	5.4	133.8	6.7
BIAURICB	119.5	4.5	123.0	5.5	121.0	2.8
MINCRANB	71.6	3.7	72.9	3.5	72.3	3.7
BIASTERI	105.9	3.6	114.3	5.0	104.6	2.5
BASIPROS	103.0	2.8	106.1	6.9	99.4	5.2
NASIPROS	64.7	3.6	71.4	6.5	65.3	4.0
NASALHGT	51.8	3.6	53.9	3.3	52.8	2.5
NASALBTH	25.2	3.1	25.4	1.0	25.7	1.1

Table 4. (cont'd)

ORBHGTLF	33.0	1.7	33.3	2.3	33.0	1.8
ORBBTHLF	41.4	1.4	42.4	0.5	41.4	1.3
BIJUGALB	113.9	3.6	117.0	4.7	111.9	5.0
ALVEOLAL	57.9	1.2	55.6	5.3	55.4	3.2
ALVEOLAB	63.7	3.3	66.1	6.0	64.0	4.6
MASTOIDH	26.8	3.6	28.1	4.0	25.7	3.2
MASTOIDW	18.6	2.9	23.4	3.8	19.3	2.6
BIMAXILB	95.3	4.5	98.9	6.8	96.4	3.5
BIFRONTB	105.0	3.3	109.0	3.9	104.4	4.9
BIORBITB	98.3	3.5	98.6	3.9	95.9	3.1
INTERORB	28.3	2.5	28.3	2.2	28.3	2.6
MALRLINF	38.0	3.1	34.6	5.1	34.9	3.4
MALRLMAX	53.0	3.8	56.9	2.2	53.5	4.5
CHEEKHGT	22.8	3.6	24.3	3.1	23.2	2.0
FORAMAGL	33.0	2.4	34.0	1.0	32.7	1.3
NASIBGCR	107.5	7.3	113.1	4.9	111.2	9.2
BRGLMDCR	116.1	5.4	120.4	3.1	111.8	6.2
LAMOPISC	94.2	3.7	98.4	2.6	95.5	4.4
BIMAXSUB	25.6	3.2	23.3	4.5	23.7	4.2
NASFROSB	16.1	3.2	18.9	1.3	16.9	2.5

	Saipan N=23		Tinian N=6		Marianas N=5		Guam N=51	
Measurement	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
MAXCRANL	183.8	7.8	184.3	7.8	179.4	3.5	184.5	7.1
NASOCCIL	180.7	7.2	179.3	6.0	176.2	5.0	180.6	7.2
BASINASI	103.3	3.9	105.2	3.1	103.6	3.0	104.9	3.7
BASIBREG	141.4	4.0	144.3	1.4	143.8	1.8	143.2	4.5
MAXCRANB	137.2	5.6	138.2	3.4	141.4	3.5	139.7	4.3
MAXFRONB	115.1	4.8	115.8	5.1	118.0	4.0	118.6	4.1
MINFRONB	96.2	3.6	99.7	2.4	96.8	5.4	97.9	4.0
BISTEPHB	110.1	6.6	111.2	4.8	113.0	5.8	111.7	5.1
BIZYGOMB	136.3	7.1	141.7	3.1	141.4	3.4	141.3*	4.6
BIAURICB	126.2	6.8	129.2	2.3	128.6	5.4	130.2	4.2
MINCRANB	73.0	4.2	74.7	4.2	75.4	3.2	75.6	4.0
BIASTERI	108.2	4.3	110.3	2.4	107.8	4.6	108.1	4.4
BASIRPOS	100.3	5.3	101.0	4.6	98.8	4.4	101.7	4.7
NASIPROS	69.3	4.2	73.0	3.9	69.0	2.9	71.6	3.5
NASALHGT	53.6	3.7	54.7	2.7	53.8	1.9	54.6	2.7
NASALBTH	25.8	2.0	27.3	2.0	26.8	1.1	26.4	2.1
ORBHGTLF	34.1	1.6	36.3	1.6	37.2	1.9	36.4	3.0
ORBBTHLF	42.3	2.4	43.2	1.8	42.8	3.0	44.2	1.7
BIJUGALB	119.1	5.5	123.0	3.2	119.8	3.8	120.2	4.1
ALVEOLAL	54.7	1.9	53.3	2.1	53.6	3.8	54.4	2.7
ALVEOLAB	65.4	3.5	67.3	1.7	64.2	2.7	67.0	3.1
MASTOIDH	29.7	3.6	29.5	2.6	26.2	3.0	28.0	2.9
MASTOIDW	20.8	3.2	19.7	1.6	21.0	3.9	19.7	2.6
BIMAXILB	100.0	5.2	104.0	4.9	99.2	4.9	102.2	4.5
BIFRONTB	107.4	3.4	111.7	2.2	108.2	4.2	108.0	3.8
BIORBITB	98.1	3.2	101.5	2.1	98.6	3.0	99.1	3.3
INTERORB	27.7	2.3	28.8	0.8	29.0	1.6	27.5	2.1
MALRLINF	38.9	3.6	38.5	3.2	38.6	2.1	39.2	3.4
MALRLMAX	58.3	5.1	58.3	2.7	57.0	2.4	58.2	3.4
CHEEKHGT	24.5	1.9	24.7	2.8	23.2	0.8	24.9	2.1
FORAMAGL	35.3	2.1	34.3	3.8	36.0	1.2	34.8	2.1
NASIBGCR	113.7	5.2	114.7	3.9	116.6	3.0	115.7	4.0
BRGLMDCR	116.6	7.3	116.5	6.5	108.4	5.7	115.5	7.2
LAMOPISC	97.5	5.2	97.7	2.3	99.0	8.6	97.2	5.4
BIMAXSUB	22.8	3.8	23.5	1.5	22.6	1.1	22.5	2.3
NASFROSB	17.0	2.4	17.7	1.5	16.8	2.4	16.4	2.5

*BIZYGOMB for Guam is based on N=29.

Table 5. A Ranking of 35 Cranial Measurements for 10 Male Samples from Micronesia Arranged According to F-Values Received in Step O of Stepwise Descriminant Function Analysis

Measurement	F-to-Enter Statistic (D.F.=9/127)
BIAURICB	13.9
BASIBREG	11.5
MAXCRANB	11.1
MAXFRONB	9.5
BIJUGALB	8.5
NASIPROS	6.2
ORBHGTLF	5.9
MALRLMAX	5.9
ORBBTHLF	5.9
BASINASI	5.7
MALRLINF	4.9
MINCRANB	4.9
BIMAXILB	4.6
BISTEPHB	4.4
ALVEOLAB	4.1
NASIBGCR	4.0
BIFRONTB	3.9
NASOCCIL	3.8
MAXCRANL	3.7
MINFRONB	3.4
BIASTERI	3.3
ALVEOLAL	3.1
FORAMAGL	2.8
BIORBITB	2.7
MASTOIDW	2.6
MASTOIDH	2.5
BRGLMDCR	2.1
BASIPROS	1.8
NASALBTH	1.7
NASALHGT	1.7
INTERORB	1.6
BIMAXSUB	1.6
CHEEKHGT	1.4
NASFROSB	1.2
LAMOPISC	0.8

Guam, Northern Marianas (Tinian, Saipan, Marianas), Palau, central and eastern Carolines (Truk, Ponape), and eastern Micronesia (Marshalls, Gilberts, & Nauru). The means and standard deviations for 36 cranial measurements for five samples are available from the author. Tables 10–14 record the results obtained through the application of multivariate procedures including stepwise discriminant function analysis.

The best classification results are those obtained for eastern Micronesia, western Carolines and Guam. However, five of the cases originally assigned to the Northern Marianas are misclassified as being from Guam. The latter finding is not unexpected given that these two regions were inhabited by the same (Chamorro) indigenous peoples. Seven of the cases originally assigned to Guam are misclassified as western Carolines.

A plot of the group means on the first two discriminant functions (Figure 3) suggests a marked separation of the Marianas from the remaining Micronesian samples and further implies an east-west division within Micronesia.

The distances obtained through the application of Mahalanobis's Generalized Dis-

Table 6. A Ranking of 35 Cranial Measurements for 10 Male Samples from Micronesia Arranged According to F-Values Received in the Final Step of Stepwise Discriminant Function Analysis

Step No.	Measurement	F-Value	$d.f._B/d.f._W$	P*
1	BIAURICB	13.9	9/127	*
2	BASIBREG	4.5	9/126	*
3	ALVEOLAL	3.5	9/125	*
4	NASIPROS	4.2	9/124	*
5	MAXFRONB	3.0	9/123	*
6	MASTOIDW	2.9	9/122	*
7	BIASTERI	2.5	9/121	*
8	BIJUGALB	2.8	9/120	*
9	ORBBTHLF	2.8	9/119	*
10	BIFRONTB	3.4	9/118	*
11	BRGLMDCR	2.0	9/117	**
12	INTERORB	1.9	9/116	**
13	MALRLINF	1.8	9/115	N.S.
14	MALRLMAX	2.5	9/114	*
15	BIMAXILB	1.9	9/113	**
16	MINCRANB	1.6	9/112	N.S.
17	BASINASI	1.6	9/111	N.S.
18	BIMAXSUB	1.8	9/110	N.S.
19	MASTOIDH	1.5	9/109	N.S.
20	ALVEOLAB	1.5	9/108	N.S.
21	BISTEPHB	1.4	9/107	N.S.
22	BASIPROS	1.4	9/106	N.S.
23	NASALBTH	1.3	9/105	N.S.
24	MAXCRANL	1.2	9/104	N.S.
25	NASALHGT	1.3	9/103	N.S.
25	MAXCRANB	1.2	9/102	N.S.
27	FORAMAGL	1.0	9/101	N.S.
28	ORBHGTLF	0.9	9/100	N.S.
29	BIORBITB	0.8	9/99	N.S.
30	NASOCCIL	0.7	9/98	N.S.
31	MINFRONB	0.6	9/97	N.S.
32	LAMOPISC	0.5	9/96	N.S.
33	NASIBGCR	0.5	9/95	N.S.
34	CHEEKHGT	0.4	9/94	N.S.
35	NASFROSB	0.3	9/93	N.S.

* $P < .01$
** $P < .05$
N.S. = not significant

tance to cranial measurements recorded in the 5 combined samples are available from the author. Figure 4 is the diagram of relationship which results from a cluster analysis of these distances. The closest association is one between Guam and the Northern Marianas. The next association, although not as strong as the latter, is that between the two Carolinian samples. The eastern Micronesian cranial sample is attracted to this latter grouping. The Marianas are well-separated from the remaining Micronesian samples.

CIRCUM-MICRONESIAN COMPARISONS

In the last section, multivariate procedures were applied to 30 cranial measurements recorded in 10 Micronesian and 28 circum-Micronesian samples. The comparative data are listed in Table 2. Because of missing measurements in excess of predetermined limits,

Table 7. Eigenvalues, Percentage of Total Dispersion, Cumulative Dispersion and Level of Significance for 9 Canonical Variables

Variable	Eigenvalue	% Dispersion	Cumulative % Dispersion	d.f.[1]	P[2]
I	3.63859	42.1	42.1	43	*
II	1.91423	22.1	64.2	41	*
III	0.77824	9.0	73.2	39	*
IV	0.59541	6.9	80.1	37	*
V	0.47053	5.5	85.6	35	**
VI	0.45268	5.2	90.8	33	**
VII	0.31051	3.6	94.4	31	N.S
VIII	0.30081	3.5	97.9	29	N.S.
IX	0.18501	2.1	100.0	27	N.S.

1 Degrees of freedom (d.f.) = (p+q-2) + (p+q-4)...
2 *p < .01. When eigenvalues are tested for significance according to Barlett's criterion: $[N-1/2(p+q)] \log_e (1+\lambda)$, where N = total number of crania, p = number of variables, q = number of groups, λ = eigenvalue, which is distributed approximately as Chi-square (Rao, 1952:373).
**P < .05
N.S. = not significant

Table 8. Canonical Coefficients for 35 Cranial Measurements Recorded in 10 Male Samples for the First Two Canonical Variables Arranged According to Decreasing Magnitude

Canonical Variable I: Variable	Coefficient	Canonical Variable II: Variable	Coefficient
ORBBTHLF	-0.25643	MAXFRONB	-0.22742
NASIPROS	-0.16478	BASINASI	0.20070
NASALHGT	0.14142	NASIPROS	0.17956
ALVEOLAL	0.12823	BIJUGALB	0.16674
BIJUGALB	0.09984	BISTEPHB	0.16646
BASIBREG	-0.09743	MALRLINF	-0.16166
MASTOIDW	0.09204	BIAURICB	-0.15031
BIMAXSUB	0.08770	ORBBTHLF	-0.13071
NASALBTH	0.08519	BIASTERI	0.12694
MAXCRANB	-0.08229	ALVEOLAL	-0.12047
BIORBITB	0.07988	FORAMAGL	0.11809
BIMAXILB	-0.07329	BIFRONTB	0.11252
INTERORB	0.07290	MINCRANB	-0.08824
BIFRONTB	0.06691	MALRLMAX	0.08628
NASOCCIL	-0.05728	INTERORB	0.07729
CHEEKHGT	0.04757	BIMAXSUB	-0.06685
BASIPROS	0.04569	MINFRONB	-0.06370
FORAMAGL	-0.04505	BIORBITB	-0.06031
MINCRANB	0.04473	NASIPROS	-0.05872
MALRLMAX	-0.04450	ALVEOLAB	-0.05696
BRGLMDCR	0.04354	ORBHGTLF	-0.05468
ALVEOLAB	0.04342	BASIPROS	-0.05412
ORBBTHLF	-0.03704	BIMAXILB	-0.05208
MASTOIDH	0.03698	MASTOIDH	0.04727
BASINASI	-0.03211	MAXCRANL	-0.04690
LAMOPISC	0.03171	MASTOIDW	0.02968
NASFROSB	-0.02816	NASALBTH	-0.02953
MALRLINF	0.02220	NASFROSB	0.02672
MAXCRANL	-0.01908	CHEEKHGT	0.02083
NASIBGCR	0.01742	MAXCRANB	-0.02075
BISTEPHB	-0.01371	NASIBGCR	-0.02028
MINFRONB	0.01180	BASIBREG	-0.01643
MAXFRONB	0.00350	BRGLMDCR	0.01439
BIAURICB	0.00011	NASOCCIL	0.01076
BIASTERI	0.00010	LAMOPISC	0.00043

Table 9. Summary of Classification Results Using
10 Male Samples
(Number of Cases Classified in Groups)

	TRK	PON	MRS	GIL	NAU	MAR	TIN	SAI	PAL	GUA
Truk	6									
Ponape		10							1	
Marshall	1		5	1						
Gilbert				7						
Nauru					7					
Marianas						5				
Tinian							6			
Saipan	2				2		1	15	1	2
Palau		1							13	
Guam						1	1	4		45
Total No. Cases Originally Assigned	6	11	7	7	7	5	6	23	14	51
No. Cases Correctly Assigned	6	10	5	7	7	5	6	15	13	45
% Correct Assignments	100.0	90.9	71.4	100.0	100.0	100.0	100.0	65.2	92.9	88.2

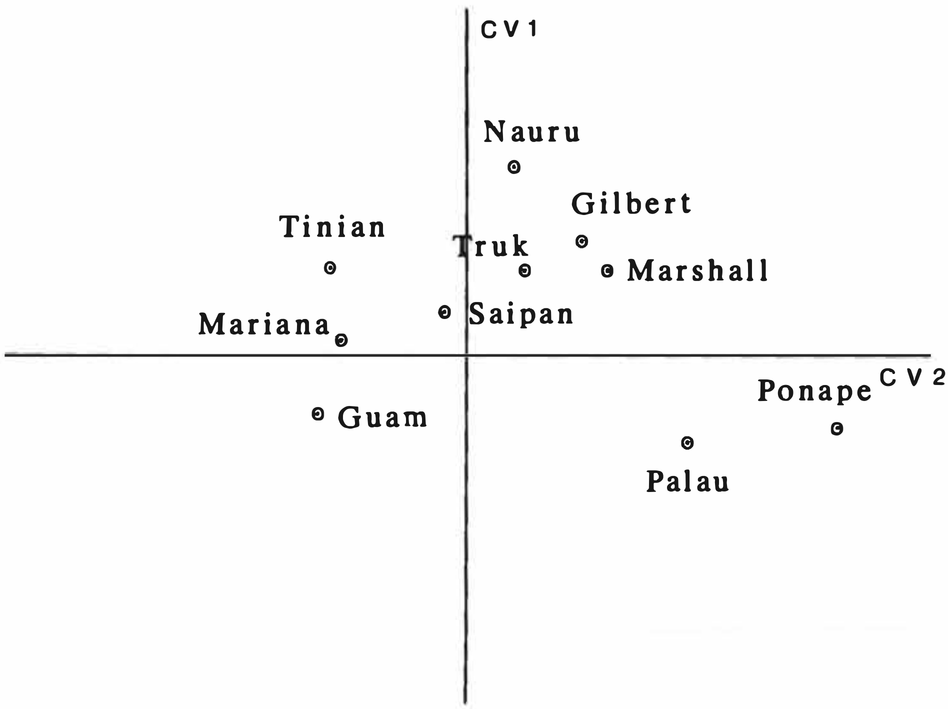

Figure 1. Plot of 10 Micronesian male samples on the first and second discriminant functions using 35 cranial measurements.

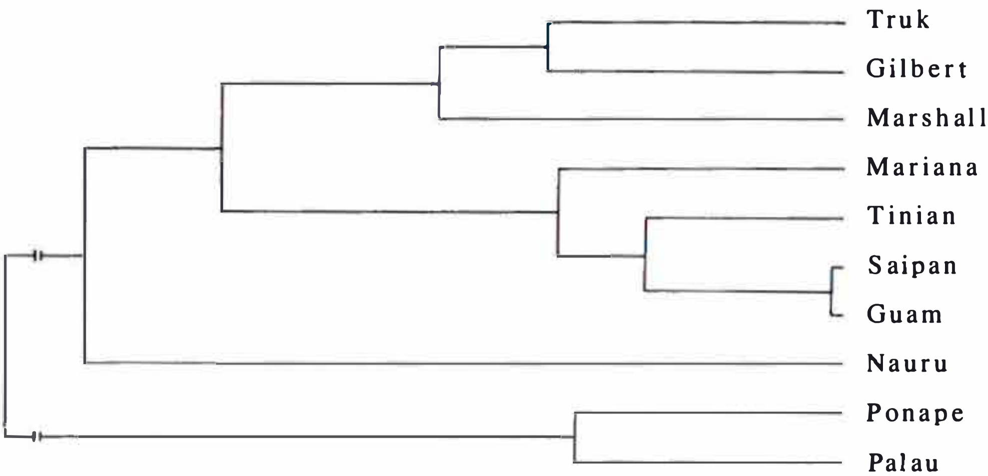

Figure 2. Diagram of relationship based on Mahalanobis' Generalized Distances for 10 Micronesian male samples using 35 cranial measurements.

Table 10. A Ranking of 35 Cranial Measurements for 5 Male Samples According to F-Values Received in Step 0 of Stepwise Discriminant Function Analysis

Measurement	F-to-Enter Statistic(D.F.=6/104)
BIAURICB	28.7
MAXCRANB	20.9
BASIBREG	17.9
BIJUGALB	17.4
MAXFRONB	16.0
ORBBTHLF	12.5
MALRLMAX	11.0
BIMAXILB	9.4
NASIPROS	9.0
BASINASI	9.0
MINCRANB	8.9
ORBHGTLF	8.5
MALRLMAX	8.3
ALVEOLAB	6.3
NASIBGCR	6.1
FORAMAGL	5.6
BISTEPHB	5.5
NASOCCIL	5.3
BIFRONTB	5.1
MAXCRANL	4.7
BIORBITB	3.7
BIMAXSUB	3.4
BIASTERI	3.1
MASTOIDW	3.0
MINFRONB	2.8
NASALHGT	2.7
BASIPROS	2.5
CHEEKHGT	2.4
NASFROSB	2.2
MASTOIDW	1.7
ALVEOLAL	1.6
LAMOPISC	1.5
NASALHGT	1.4
BRGLMDCR	0.9

Table 11. A Ranking of 35 Cranial Measurements for 5 Male Samples According to F-Values Received in the Final Step of Stepwise Discriminant Function Analysis

Step No.	Measurement	F-Value	$d.f._b/d.f._w$	P*
1	BIAURICB	28.7	4/132	*
2	MAXCRANB	4.9	4/131	*
3	ORBBTHLF	5.0	4/130	*
4	BIFRONTB	5.1	4/129	*
5	BIJUGALB	4.7	4/128	*
6	BIASTERI	4.4	4/127	*
7	NASIPROS	3.7	4/126	*
8	ALVEOLAL	3.4	4/125	*
9	MAXFRONB	4.1	4/124	*
10	MASTOIDW	2.9	4/123	**
11	NASOCCIL	3.5	4/122	*
12	NASALHGT	2.7	4/121	**
13	BASINASI	2.3	4/120	N.S.
14	BIMAXILB	2.0	4/119	N.S.
15	BISTEPHB	2.0	4/118	N.S.
16	BASIBREG	2.4	4/117	N.S.
17	FORAMAGL	1.5	4/116	N.S.
18	ALVEOLAB	1.3	4/115	N.S.
19	BIORBITB	1.3	4/114	N.S.
20	INTERORB	1.4	4/113	N.S.
21	MINCRANB	1.4	4/112	N.S.
22	BIMAXSUB	1.5	4/111	N.S.
23	NASALBTH	1.3	4/110	N.S.
24	BASIPROS	1.1	4/109	N.S.
25	MALRLINF	1.1	4/108	N.S.
26	MALRLMAX	1.1	4/107	N.S.
27	MINFRONB	1.2	4/106	N.S.
28	LAMOPISC	0.8	4/105	N.S.
29	ORBHGTLF	1.1	4/104	N.S.
30	MAXCRANL	0.7	4/103	N.S.
31	MASTOIDH	0.5	4/102	N.S.
32	NASIBGCR	0.3	4/101	N.S.
33	NASFROSB	0.2	4/100	N.S.
34	BRGLMDCR	0.2	4/ 99	N.S.
35	CHEEKHGT	0.1	4/ 98	N.S.

* $P < .01$
** $P < .05$
N.S. = not significant

Table 12

Eigenvalues, Percentage of Total Dispersion, Cumulative Dispersion and Level of Significance for 4 Canonical Variables

Variable	Eigenvalue	% Dispersion	Cumulative % Dispersion	d.f.[1]	P[2]
I	2.87923	57.7	57.7	38	*
II	1.29162	25.9	83.6	36	*
III	0.43795	8.7	92.3	34	**
IV	0.38218	7.7	100.0	32	N.S.

1 Degrees of freedom (d.f.) = (p+q-2) + (p+q-4)...
2 *p < .01 when eigenvalues are tested for significance according to Bartlett's criterion: $\{N-1/2\,(p+q)\ \log_e(1+\lambda)$, where N = total number of crania, p = number of variables, q = number of groups, λ = eigenvalue, which is distributed approximately as chi-square (Rao, 1952:373)
** P < .05
N.S.= not significant

Table 13. Canonical Coefficients for 35 Cranial Measurements Recorded in 5 Micronesian Male Samples for the First Two Canonical Variables Arranged According to Decreasing Magnitude

Canonical Variable-I: Variable	Coefficient	Canonical Variable-II: Variable	Coefficient
ORBBTHLF	-.27642	BIJUGALB	.23336
BIFRONTB	.13572	MAXFRONB	-.21482
MASTOIDW	.12520	INTERORB	.17750
NASALHGT	.10155	NASIPROS	.16454
MAXFRONB	-.09518	FORAMAGL	.14379
INTERORB	.08864	BISTEPHB	.12643
BIMAXILB	-.08574	ALVEOLAL	-.12496
BASIBREG	-.07667	BIAURICB	-.11708
MAXCRANB	-.07393	BASINASI	.11660
NASALBTH	-.06908	BIASTERI	.11610
BASINASI	.06720	BIORBITB	-.11401
BIORBITB	.06559	MINCRANB	-.10091
BIJUGALB	-.06414	MINFRONB	-.09480
BIAURICB	-.06327	ORBBTHLF	-.09042
BISTEPHB	.06273	NASALHGT	-.08078
NASIPROS	-.06209	NASOCCIL	.08004
BIMAXSUB	.05986	MALRLINF	-.07895
MALRLINF	-.05503	BIMAXSUB	-.07106
NASOCCIL	-.05165	MALRLMAX	.06847
MAXCRANL	-.04663	BIFRONTB	.06709
CHEEKHGT	.04332	MAXCRANL	-.06449
BIASTERI	.04177	NASALBTH	-.06223
BRGLMDCR	.03181	MASTOIDW	-.06040
ALVEOLAL	.03000	MASTOIDH	.04141
ORBHGTLF	-.02944	ALVEOLAB	-.03657
LAMOPISC	.02707	ORBHGTLF	-.03506
MASTOIDH	.02674	BASIPROS	-.03428
MALRLMAX	-.01856	BASIBREG	.03247
NASIBGCR	.01690	CHEEKHGT	-.02555
BASIPROS	.01636	BIMAXILB	-.02402
MINFRONB	-.01333	NASIBGCR	-.02165
ALVEOLAB	.00795	LAMOPISC	-.01023
MINCRANB	.00620	MAXCRANB	.00785
NASFROSB	-.00459	NASFROSB	-.00503
FORAMAGL	.00012	BRGLMDCR	.00185

Table 14. Summary of Classification Results Using 5 Combined Micronesian Male Samples (Number of Cases Classified in Groups)

	CNECAR	EASMIC	NORMAR	WESCAR	GUAM
Central & Eastern Carolines	13	2	1	1	
Eastern Micronesia		20	1		
Northern Marianas	1	2	26		5
Western Carolines	1			13	
Guam				7	44
Total No. Cases Originally Assigned	17	21	34	14	51
No. Cases Correctly Assigned	13	20	26	13	44
% Correct Assignments	76.5	95.2	76.5	92.9	86.3

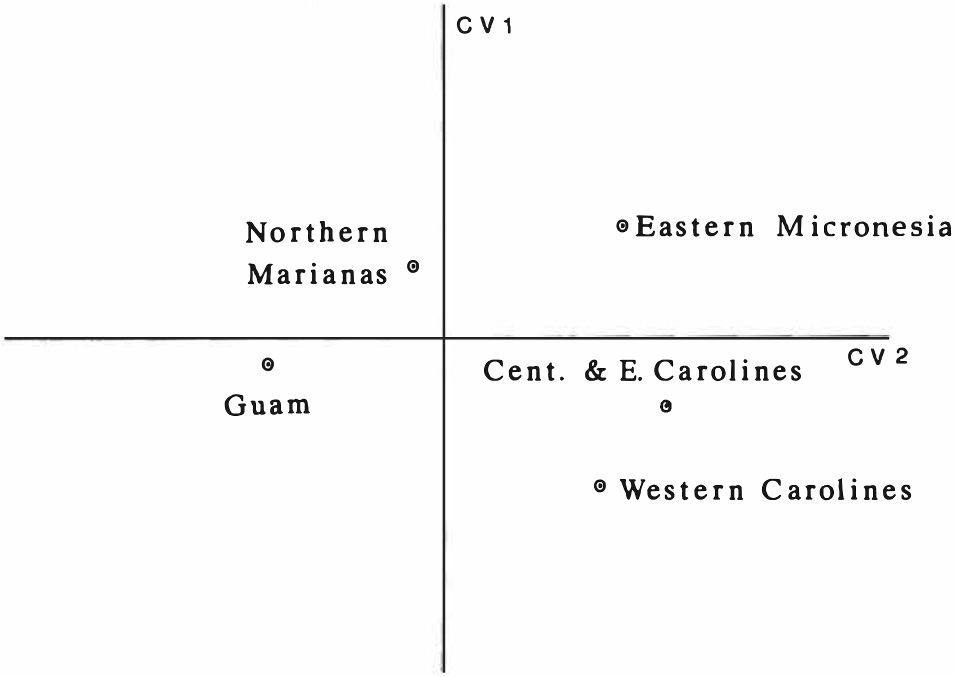

Figure 3. Plot of 5 combined Micronesian male samples on the first and second discriminant functions using 35 cranial measurements.

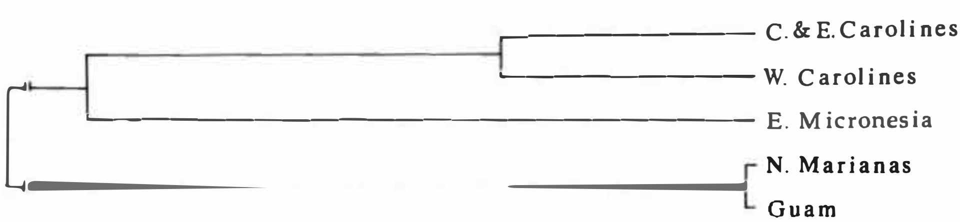

Figure 4. Diagram of relationship based on Mahalanobis' Generalized Distances for 5 combined Micronesian male samples using 35 cranial measurements.

five of the original 35 measurements, ALVEOLAL, MALRLINF, MALRLMAX, BIMAXSUB and NASFROSB, were eliminated.

A ranking of the 30 measurements, arranged according to F-values received in Step O and the final step of discriminant anlaysis are listed in Tables 15 and 16, and eigenvalues and the percentage of dispersion for 30 functions are presented in Table 17. The first six functions account for nearly 30 percent of the dispersion. Canonical coefficients for 30 cranial measurements recorded in 38 male samples for the first two canonical variables are presented in Table 18.

Table 15. A Ranking of 30 Cranial Measurements for 38 Male Samples Arranged According to F-values Received in Step 0 of Stepwise Discriminant Function Analysis

Measurement	F-to-Enter Statistic D.F.=37/1507
MAXCRANB	29.44
BASIBREG	24.86
BIAURICB	22.42
BASINASI	21.66
MAXFRONB	21.23
MAXCRANL	20.71
BISTEPHB	20.16
NASOCCIL	18.33
BASIPROS	17.46
MINCRANB	17.32
ORBBTHLF	16.47
BIORBITB	13.78
ORBHGTLF	13.32
NASIPROS	12.88
BIJUGALB	12.69
BIFRONTB	12.56
CHEEKHGT	12.36
NASIBGCR	11.74
ALVEOLAB	11.66
NASALHGT	10.10
BRGLMDCR	9.48
INTERORB	7.55
MASTOIDH	7.30
LAMOPISC	7.22
BIMAXILB	6.84
MINFRONB	6.49
MASTOIDW	5.95
BIASTERI	4.69
FORAMAGL	4.67
NASALBTH	4.30

The classification results obtained at the end of the stepping process can be summarized as follows (Table 19). Except for Saipan and Palau, the percentage of correct classifications among the Micronesian samples is generally high. Nine of the misclassified Guam cases were assigned to Polynesian (especially Hawaiian) samples. Only seven of the 23 cases originally assigned as Saipan were correctly placed. Eight of the latter were misclassified as other Micronesians, three were misclassified as Fiji and three more were misclassified as Vietnam or Laos. Five of the cases originally assigned to Palau were misclassified as Indonesian (Celebes, Java, Sumatra, Southern Moluccas) samples.

Figure 5 is a plot of the 38 group means on the first and second discriminant functions. The means cluster into four, relatively distinct, constellations. The first comprises all the Melanesian and Australian samples and the sample of Ponapean crania. A second includes all the Southeast Asian and East Asian samples. The Polynesian samples, with some overlap with eastern Micronesia, form a separate group. Guam and the Northern Marianas constitute a fourth cluster. Palau aligns with Indonesian samples.

Finally, Mahalanobis' Generalized distance was applied to 30 measurements recorded in 38 samples. The d-squared results are available from the author. Figure 6 is the diagram of relationship obtained from a cluster analysis of the latter. The arrangement is similar to the plot of the group means. A basic division occurs between a Melanesian-

Table 16. A Ranking of 30 Cranial Measurements for 38 Male Samples Arranged According to F-Values Recorded in the Final Step of Stepwise Discriminant Function Analysis

Step No	Measurement	F-Value	$d.f_B/d.f_w$	P*
1	MAXCRANB	29.4	37/1507	*
2	BASINASI	21.7	37/1506	*
3	BIORBITB	17.7	37/1505	*
4	MINCRANB	14.2	37/1504	*
5	BASIPROS	10.3	37/1503	*
6	MAXCRANL	9.8	37/1502	*
7	BIAURICB	9.7	37/1501	*
8	NASIPROS	9.5	37/1500	*
9	BASIBREG	8.7	37/1499	*
10	INTERORB	8.7	37/1498	*
11	NASOCCIL	8.7	37/1497	*
12	ALVEOLAB	6.8	37/1496	*
13	BIJUGALB	6.2	37/1495	*
14	NASALHGT	6.1	37/1494	*
15	BIFRONTB	6.2	37/1493	*
16	MASTOIDH	5.5	37/1492	*
17	NASIBGCR	5.0	37/1491	*
18	ORBBTHLF	4.5	37/1490	*
19	MINFRONB	4.2	37/1489	*
20	ORBHGTLF	3.9	37/1488	*
21	CHEEKHGT	4.3	37/1487	*
22	MAXFRONB	3.6	37/1486	*
23	BISTEPHB	4.8	37/1485	*
24	BRGLMDCR	3.7	37/1484	*
25	FORAMAGL	3.7	37/1483	*
26	NASALBTH	3.6	37/1482	*
27	BIMAXILB	2.8	37/1481	*
28	BIASTERI	2.7	37/1480	*
29	MASTOIDW	2.6	37/1479	*
30	LAMOPISC	2.4	37/1478	*

* $P < .01$

Australian constellation and one that contains all the remaining samples. Within the former, a further distinction is made between Australia and Melanesia. The Ponape sample falls within the eastern Melanesian sub-branch of this latter cluster. The remaining separation is primarily a three-way split between Micronesia, Polynesia and Southeast Asia. Truk and Saipan cluster with the Polynesian samples. With the exception of Guam, a separation between eastern and western Micronesia within an essentially Micronesian cluster is evident in this representation which parallels the grouping observed in Figure 5.

Discussion and Conclusions

Some comparisons of the present craniometric results with previous work in anthropometry, linguistics and archaeology are now in order. This discussion will focus on examining the relationships within Micronesia and between Micronesia and the surrounding regions.

Linguistically, Micronesia contains two distinct Austronesian language groups (Bender 1971). The languages in western Micronesia, including the Marianas, Palau and possibly Yap are classified in a western Malayo-Polynesian language group, one which is most closely related to languages of Southeast Asia. Most of the remaining languages, of

Table 17. Eigenvalues, Percentage of Total Dispersion, Cumulative Dispersion and Level of Significance for 30 Canonical Variables

Variable	Eigenvalue	% Dispersion	Cumulative % Dispersion	d.f.[1]	P[2]
I	2.66813	36.7	36.7	66	*
II	1.21616	16.8	53.5	65	*
III	0.71583	9.8	63.3	64	*
IV	0.49204	6.8	70.1	63	*
V	0.36437	5.0	75.1	62	*
VI	0.30100	4.1	79.2	61	*
VII	0.25382	3.5	82.7	60	*
VIII	0.20026	2.8	85.5	59	*
IX	0.15253	2.1	87.6	58	*
X	0.14409	2.0	89.6	57	*
XI	0.12073	1.6	91.2	56	*
XII	0.10581	1.5	92.7	55	*
XIII	0.08911	1.2	93.9	54	*
XIV	0.07846	1.0	94.9	53	*
XV	0.06058	0.9	95.8	52	*
XVI	0.05854	0.8	96.6	51	*
XVII	0.04978	0.7	97.3	50	*
XVIII	0.03788	0.5	97.8	49	*
XIX	0.03179	0.5	98.3	48	**
XX	0.02922	0.4	98.7	47	**
XXI	0.02090	0.3	98.9	46	N.S.
XXII	0.01804	0.2	99.2	45	N.S.
XXIII	0.01460	0.2	99.4	44	N.S.
XXIV	0.01228	0.1	99.6	43	N.S.
XXV	0.00859	0.1	99.7	42	N.S.
XXVI	0.00771	0.1	99.8	41	N.S.
XXVII	0.00649	0.1	99.9	40	N.S.
XXVIII	0.00366	0.05	99.95	39	N.S.
XXIX	0.00188	0.03	99.98	38	N.S.
XXX	0.00146	0.02	100.0	37	N.S.

1 Degrees of freedom (d.f.) = (p+q-2)+(p+q-4)...

2 *p < .01 when eigenvalues are tested for significance according to Bartlett's criterion: [N-1/2 (p+q)] $\log_e(1+\lambda)$, where N = total number of crania, p = number of variables, q = number of groups, λ = eigenvalue, which is distributed approximately as chi-square (Rao, 1952:373)
** p < .05
N.S. = not significant

eastern and central Micronesia (e.g., Truk, Ponape, Kosrae, Marshalls and Gilberts), belong to Nuclear Micronesian. The latter share linguistic ties with eastern Melanesia, especially northern Vanuatu and the southeastern Solomons (Craib 1983).

The archaeological record substantiates this east-west division and further agrees that settlement of Micronesia occurred from two opposite directions, the western high islands having been settled first from insular Southeast Asia followed by a later settlement in eastern Micronesia from eastern Melanesia with subsequent cultural expansion westward (Bellwood 1979: 282, Craib 1983).

There have been very few skeletal studies of Micronesians in recent years. Hunt's summary of earlier skeletal studies in Micronesia requires little in the way of augmentation (Hunt 1950). Previous anthropometric studies provide a more extensive base for viewing human variation within the region. Howells' (1970, 1973) multivariate comparisons of earlier anthropometric data recorded in living inhabitants of the Pacific (in-

Table 18. Canonical Coefficients for 30 Cranial Measurements Recorded in 38 Male Samples for the First Two Canonical Variables Arranged According to Decreasing Magnitude

Canonical Variable I		Canonical Variable II	
Variable	Coefficient	Variable	Coefficient
BIORBITB	-0.16761	MINCRANB	0.10905
ORBHGTLF	0.11735	NASALHGT	-0.10250
BIJUGALB	0.11367	NASALBTH	0.09997
CHEEKHGT	0.10099	BIAURICB	0.00249
BASINASI	0.08506	ALVEOLAB	0.09329
INTERORB	0.08438	ORBHGTLF	-0.08844
ALVEOLAB	-0.08267	NASOCCIL	-0.08632
BIFRONTB	-0.07142	INTERORB	0.08435
BASIPROS	-0.06916	ORBBTHLF	-0.08227
NASIPROS	0.06810	NASIPROS	0.08222
NASALHGT	-0.05532	BASINASI	-0.06632
MINFRONB	-0.05529	BIORBITB	-0.06439
BISTEPHB	0.05492	MAXCRANL	0.06051
MINCRANB	0.05257	BIFRONTB	0.05850
MAXCRANB	-0.05111	MAXCRANB	0.05731
ORBBTHLF	-0.04484	MAXFRONB	0.05459
BASIBREG	0.04184	NASIBGCR	-0.05126
MASTOIDW	0.04030	BASIPROS	-0.04807
MAXCRANL	0.03145	MASTOIDH	-0.04717
BIMAXILB	0.03042	CHEEKHGT	-0.04210
NASALBTH	0.02688	FORAMAGL	0.03969
LAMOPISC	0.02509	BISTEPHB	-0.03648
BIASTERI	-0.02016	BIASTERI	0.03134
FORAMAGL	0.01863	LAMOPISC	-0.02261
NASIBGCR	-0.01605	MASTOIDW	-0.01935
MAXFRONB	0.01132	BIMAXILB	0.00945
NASOCCIL	0.01031	MINFRONB	0.00726
MASTOIDH	0.00901	BRGLMDCR	0.00688
BIAURICB	0.00249	BIJUGALB	-0.00311
BRGLMDCR	-0.00181	BASIBREG	0.00180

cluding Micronesia) is one of the most extensive and reliable. For Micronesia, Howells notes a marked separation between the Marianas (Yap and Palau included) and the rest of Micronesia (Howells 1973). Two additional major divisions recognized by Howells are those in eastern Micronesia and the Caroline Islands (excluding Yap and Palau). He further notes considerable overlap between the latter and Melanesia.

The results of the present study generally agree with the above evidence from archaeology, linguistics, and anthropometry in separating Guam and the Marianas from the rest of Micronesia. A marked east-west dichotomy within Micronesia and the association of the two eastern Micronesian samples (Marshalls & Gilberts), found in the present results, is also consistent with other evidence. The relatively isolated placement of Palau and Nauru agrees with linguistic impressions. The association of Truk and eastern Micronesia found in the present study is not unexpected given linguistic affinities of eastern and central Micronesia mentioned earlier. The Ponape-Palau association, found in the present results, is not supported by the linguistic evidence available. Combining Truk and Ponape into a single (central and eastern Carolines) sample confirms this association. Given the likelihood that there has been considerable contact between all the Micronesian islands (Bellwood 1979), perhaps no special explanation is needed. In summary, with the excep-

Table 19. Summary of Classification Results Using
38 Male Samples(Number of Cases Classified in Groups)

	PHL	ADR	WA	GUA	TAS	VAN	HK	LSU	SML	VET	TAH	SUL	BOR	SEP
Philippines	16	2					2							1
Admiralty	1	37			1	2		2	2	1	1	2		12
W. Australia			37		2	1	1							
Guam				31			1		1			1		
Tasmania			1		20				1					
Vanuatu					6	36			1	1				4
Hong Kong	5	1		2			77	2		1				
L. Sundas			2			1	1	14	3	1		2	4	1
S. Moluccas	2	4				4		1	25				2	3
Vietnam					1	1				12		2	1	
Tahiti		1									21			
Sulu	1								1	1		17	2	
Borneo						1	1	1		2		2	12	1
Sepik		4				3	1	1	2					49
Cambodia														
Celebes	6	1					1	2	1	1		1	1	1
Easter							1				1			
Fiji		1	1	1		2			1		1		1	
Hawaii				1								1		
Japan	1			1			1	2		4		4	1	
Java	4						1	3	2	7	1	5	3	1
Laos	1						2			1		2	1	1
Truk	1													
Murray R.			12		8									3
Marquesas									2		9			
New Britain		1	1		2	1		1	2					7
New Zealand	1	5					2	1	2	2	1			
Tonga-Samoa						6								
Ponape														
Marshall														1
Gilbert														
Nauru														
N. Marianas														
Tinian				1										
Saipan				2						2		1		
Palau									1					
Sumatra		1	1	1	1		1	1	2	1		1	4	
Burma		1												
Total No. Cases Originally Assigned	29	79	47	51	26	84	104	45	61	30	33	38	35	74
No. Cases Correct Assig.	16	37	37	31	20	36	77	14	25	12	21	17	12	49
% Correct Assigned	55.2	46.8	78.7	60.8	76.9	42.9	74.0	31.1	41.0	40.0	63.6	44.7	34.3	66.2

Table 19 (cont'd)

	CAM	CEL	EAS	FIJ	HAW	JAP	JAV	LAO	TRK	MRB	MRQ	NBR	NZ	TGS
Philippines	1	3				1	1	1		1				
Admiralty			1	2			1			3			5	
W. Australia				1								1		
Guam					6			2		1	1		1	1
Tasmania										6				1
Yanuatu				8								10		
Hong Kong		1			1	2	1	1	1				1	
L. Sundas	2	1		2	1		1	1				2	2	2
S. Moluccas	2	3					1		1		3		6	
Vietnam						3	3							
Tahiti					1						5		3	1
Sulu	4					2	2	3						1
Borneo	2	4					1			1				
Sepik							1	1		1		2		
Cambodia	10	1												
Celebes	3	9					1	5			1			
Easter			52	2					1		2			
Fiji				15	1					1	1			1
Hawaii		1			34	1	1				3			2
Japan		2	1			28	1	1	2				1	
Java	5	3			1		25	4						2
Laos	2					1		17						
Truk									5					
Murray				1						57		2		
Marquesas				1	3				1		27	1	5	
New Britain			1	2						6		49		
New Zealand			2		2	1					6	2	35	1
Tonga	1			1	3									6
Ponape				1								1		
Marshall														
Gilbert											1			
Nauru				1										
N. Marianas														
Tinian														
Saipan			1	3				1	2					
Palau		2		1			1						1	
Sumatra	1	1	2			3	1							
Burma	1	2				2								
Total No. Cases Originally Assigned	11	41	64	32	49	65	73	29	6	85	51	85	70	12
No. Cases Correct Assigned	10	9	52	15	34	28	25	17	5	57	27	49	35	6
% Correct Assigned	90.9	22.0	81.3	46.9	69.4	43.1	34.2	58.6	83.3	67.1	52.9	57.6	50.0	50.0

Table 19. (cont'd)

	PON	MRS	GIL	NAU	MAR	TIN	SAI	PAL	SUM	BUR
Philippines									1	
Admiralty	2		1	2				1		2
W. Australia	1									
Guam						3	3			
Tasmania							1	1		
Vanuatu	7		2	2		1				
Hong Kong				1			1		5	1
L. Sundas					1					1
S. Moluccas								2	1	1
Vietnam		1			1	1	2			2
Tahiti		1								
Sulu		1			1	1	1			
Borneo			2			1		1	2	1
Sepik	4	1	1	2				1		
Cambodia										
Celebes	1							1	4	1
Easter				2			3			
Fiji	2			2				1		
Hawaii					4		1			
Japan				1			4		6	3
Java			2				1		1	1
Laos								1		
Truk										
Murray								1		
Marquesas		1						1		
New Britain	4	1		1			1			
New Zealand				3			1		2	1
Tonga				1						
Ponape	8						1			
Marshall		5					1			
Gilbert			5	1						
Nauru				4			1	1		
N. Marianas					5					
Tinian						5				
Saipan		1		1		2	7			
Palau	1							6	1	
Sumatra					1		1	1	11	3
Burma										10
Total No. Cases Originally Assigned	11	7	7	7	5	6	23	14	39	16
No. Cases Correct Assig.	8	5	5	4	5	5	7	6	11	10
% Correct Assign	72.7	71.4	71.4	57.1	100.0	83.3	30.4	42.9	28.2	62.5

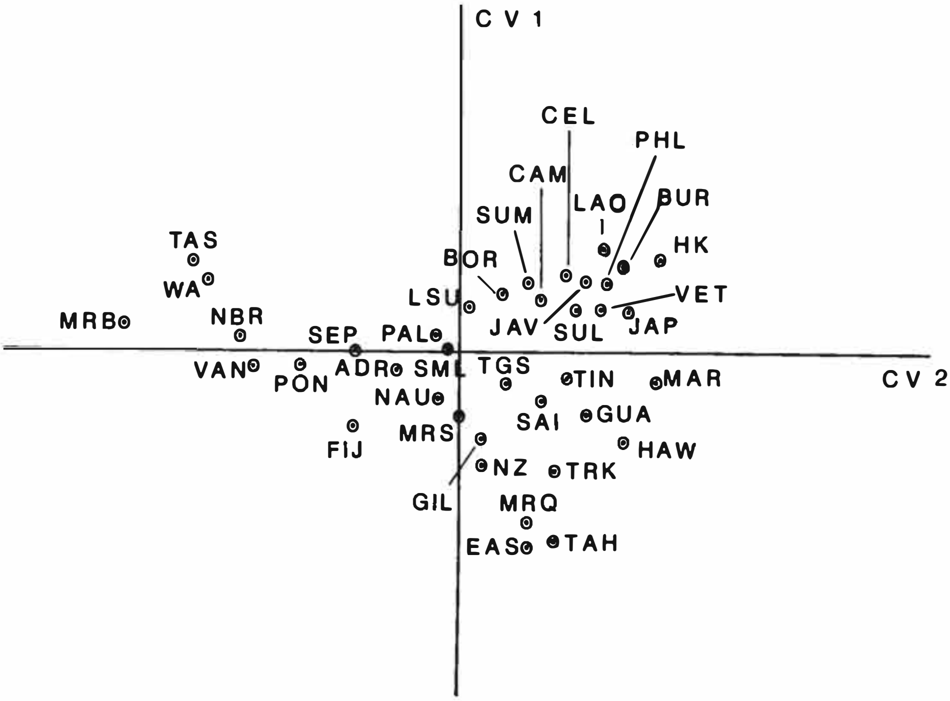

Figure 5. Plot of 38 male samples on the first and second discriminant functions using 30 cranial measurements.

tion of the similarities between the Palau and central/eastern Caroline cranial series, skull differences closely parallel relationships based on language and studies of living peoples.

Casting a larger net and viewing Micronesian cranial variability within the larger context of the Pacific and Asia allows the issue of Micronesian origins to be addressed. It has been shown that the present craniometric results are generally supportive of the linguistic and archaeological view that an east-west dichotomy exists within Micronesia. Ponape's association with eastern Melanesian samples may indicate an eastern Melanesian origin. However, given that this is the only Melanesian connection found in the present results, the association may merely indicate evidence of contact between Melanesia and Micronesia. On the other hand, the craniometric affinities between Palau and the Marianas and several of the Indonesian samples generally support a separate origin for the peoples of western Micronesia.

Some of the pairings found in Figure 6 (e.g., the grouping of Saipan with New Zealand, Tonga and Hawaii and the cluster which pairs Truk and Easter Island) appear, at first glance, untenable. Inspection of the original d-squared results, however, helped to clarify some of these associations. For example, the d-squared results indicate a closeness between Saipan and New Zealand, but equally close to Saipan are Vietnam, Guam, Japan and Tinian. This latter observation would argue for considerable Asiatic affinity of Saipan crania. Conversely, Guam's association with the Marshalls and Gilberts is an apparent

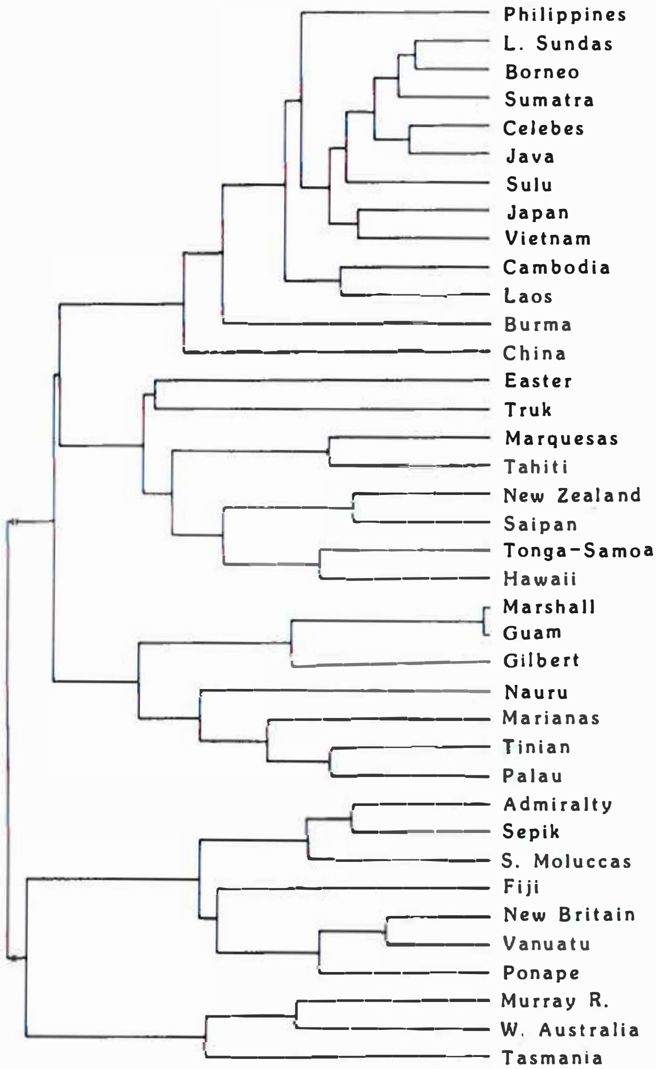

Figure 6. Diagram of relationship based on Mahalanobis' Generalized Distances for 38 male samples using 30 cranial measurements.

trick of the clustering process. The d-squared values would place most of the Marianas, Polynesian, insular and mainland Southeast Asian samples closer to Guam than either the Marshalls or Gilberts. The plot, however, does correctly suggest a willingness of Micronesians to align with Polynesians. This relationship is reiterated in the plot of the group means on the first two functions of the stepwise discriminant analysis. Particularly close is the relationship between New Zealand, Tonga and the Marshalls and Gilberts. The Trukese also fall within the Polynesian sphere in this representation. Further afield are the Mariana samples.

Unexpectedly, and despite the dual origin of culture and people in Micronesia, the present craniometric results suggest a basic continuity within Micronesia. While there is overlap, Micronesians sort out much the way Polynesians do. All the Micronesian, except Ponape, and Polynesian samples fall within a larger constellation which contains all the insular and mainland Southeast Asian samples, one which is well differentiated from the Australo-Melanesian grouping. This arrangement supports current and previous work in physical anthropology, including studies of dental traits (Katich and Turner 1974, Turner 1982, 1985, 1986), dental and facial measurements (Brace 1981), craniometric and anthropometric data (Howells 1970, 1973, 1979; Peitrusewsky 1984) and genetic lines of evidence (Serjeantson 1984), which have demonstrated a marked biological distinction between Polynesians and Melanesians. Recent studies of Lapita-associated skeletal remains (e.g., Pietrusewsky 1985) further suggests that Polynesians are not of Melanesian origin.

The craniometric and other biological differences between Melanesia [including the Bismarck Archipelago region, an area suggested by archaeologists (e.g. Spriggs 1985) as the likely source of Lapita or Polynesian culture] and Polynesia are of such a magnitude that derivation of the latter from a Melanesian source is most unlikely.

Biologically, Polynesians and Micronesians share more in common with insular and mainland Southeast Asian groups than they do with Melanesians. While western and eastern Micronesia may have been settled independently from a Southeast Asian source, there is little, if any, evidence from physical anthropology to support a Melanesian source for either Micronesians or Polynesians.

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