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A Comparative Analysis of Cranial Variation in Two Recent Human Populations

Patrick J. Key
University of Tennessee, Knoxville

To the Graduate Council:

I am submitting herewith a thesis written by Patrick J. Key entitled "A Comparative Analysis of Cranial Variation in Two Recent Human Populations." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Arts, with a major in Anthropology.

Fred H. Smith, Major Professor

We have read this thesis and recommend its acceptance:

R.L. Jantz, William M. Bass

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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William M. Bass

Accepted for the Council:

L. Evans Roth

Vice Chancellor
Graduate Studies and Research

A COMPARATIVE ANALYSIS OF CRANIAL VARIATION IN TWO RECENT HUMAN POPULATIONS

A Thesis

Presented for the

Master of Arts

Degree

The University of Tennessee, Knoxville

Patrick J. Key

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ABSTRACT

This study examines differences in craniometric variation between two recent human populations in light of tooth size. A large-toothed group is represented by Australian Aborigines from the lower Murray River region and a relatively small-toothed group is represented by protohistoric Plains Amerindians from the Larson Site in South Dakota.

The craniometric variation of the two populations is examined by multivariate statistical techniques to determine if their crania are structured along similar lines. Metric differences between the groups are then examined along the structural dimensions common to both groups.

The crania of the two groups were found to be fairly similar structurally, although this phase of the analysis was difficult to interpret. It appears that the males of the two groups differ primarily in terms of facial prominence, while the females differ somewhat in the structuring of the frontal bone.

When the metrical differences between the groups are examined along the generalized structural lines common to both groups, some interesting patterns of differences arise. Some of these differences are interpretable in light of what is currently known about the functional significance of cranio-facial architecture. Other differences, of course, are not interpretable within this framework. These differences probably result from other factors, unrelated to tooth size, which affect cranial shape.

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I. INTRODUCTION

A Brief Survey of the Literature

Multivariate studies of human craniometric variation are numerous. The cranium is a structure well suited to this type of analysis. Cranial measurements are relatively easily and precisely defined, and they display a great deal of relevant interpopulation variation (Jantz 1977: 162). Few researchers would disagree that cranial variation is best measured by multivariate rather than univariate methods since an individual is treated as a vector of measurements taken simultaneously rather than being partitioned into a series of individual observations (Howells 1969: 313). The individual thus defines a point in multidimensional space and can be dealt with much more meaningfully than in a univariate context.

Multivariate techniques have been applied with several different objectives in mind. Most commonly, researchers are concerned with determining the population relationships among a number of groups (Giles 1976; Howells 1973; Jantz 1977; Lin 1973; Lyon 1970; Morant 1928; Pietrusewsky 1973, 1977; Rösing and Schwidetzky 1977; Schwidetzky 1972; Schwidetzky and Rösing 1976). In this case, it is usually assumed that similarity in cranial morphology reflects biological similarity. Although the actual genetic basis of cranial morphology is not fully understood, the results of this type of analysis are usually consistent and biologically meaningful.

Multivariate analysis of craniometric data has also been applied to studies of microevolution (Barnard 1935; Bennett and Hulse 1966; Berry, Berry and Ucko 1967; Jantz 1972, 1973; Laughlin and Jørgensen 1956). This approach demands that the skeletal samples have well defined temporal and geographical parameters. Also, the tacit assumption is made that morphological change reflects an underlying genetic change whether through drift, natural selection, mutation or gene flow. This is not to totally discount the environmental components of cranial shape, but their effects are usually difficult to isolate and interpret.

A slight variation of the two previous approaches is applying multivariate analysis of craniometric data to specific archaeological problems (Howells 1966, 1976; Jantz 1974; Owsley and Jantz 1978; Rightmire 1970a, 1970b) or evolutionary problems (Bilsborough 1973; Corruccini 1974, 1975, 1976; Howells 1974; Rightmire 1975; Stringer 1974a, 1974b; Thorne and Wilson 1977). This approach should be used with caution when attempting to analyze "unknown" specimens in terms of the patterns of variation exhibited by known groups, since their variation may not have the same meaning (Corruccini 1978: 142; Oxnard 1973: 145-168).

A well known application of craniometric analysis is the classification of unknowns in an archaeological or forensic context (Giles 1970; Giles and Elliot 1962; Howells 1970; Van Vark 1970). These commonly take the form of discriminant functions that classify individuals into specific racial and/or sexual categories. The only

drawback with these analyses is that they work best on the reference samples from which they were derived.

Finally, multivariate analyses have been conducted that are largely exploratory in nature (Benfer 1975; Brown 1967; Howells 1957, 1971; Landauer 1962; Lombardi 1976; Solow 1971). In this case, the researchers are concerned with defining the underlying patterns of cranial variation to ascertain the relationships among various structures and variables within the cranium. The analysis presented here falls into this category.

The Problem

This study deals with the patterns of craniometric variation in two recent human populations: a large-toothed population represented by Australian Aborigines from the lower Murray River, and a relatively small-toothed population represented by the Protohistoric Plains Amerindians from the Larson Site in South Dakota.

Australian Aborigines, as a group, possess the largest teeth of any contemporary human population (Cadien 1972; Campbell 1925; Wolpoff 1971) (refer to Table 1). They also make extensive use of their teeth both in masticatory and non-masticatory activities (Gould 1968; Molnar 1972). They are characterized by a fairly "primitive" cranial architecture including massive brow ridges, buttressed zygomatics, a long, low cranial vault, and large mastoids.

The Arikara, on the other hand, have dental dimensions falling into the lower-middle range of modern human variation (refer to Table 2).

TABLE 1. AUSTRALIAN ABORIGINE DENTAL STATISTICS. *

SEX	TOOTH	MESIO-DISTAL DIAMETER			BUCCO-LINGUAL DIAMETER		
		N	MEAN	RANGE	N	MEAN	RANGE
SEXES POOLED							
UPPER							
	CENTRAL INCISOR	56	9.4	8.5 - 10.0	93	7.9	7.0 - 9.0
	LATERAL INCISOR	78	7.6	6.5 - 9.0	126	6.9	6.0 - 8.5
	CANINE	116	8.4	6.5 - 9.5	159	9.0	7.5 - 11.0
	THIRD PREMOLAR	124	7.8	7.0 - 9.0	163	10.3	8.5 - 12.0
	FOURTH PREMOLAR	89	7.2	6.5 - 8.2	168	10.1	8.5 - 12.0
	FIRST MOLAR	198	11.4	10.0 - 13.0	255	12.8	11.5 - 14.8
	SECOND MOLAR	168	10.9	10.0 - 12.5	241	13.1	11.0 - 16.0
	THIRD MOLAR	142	10.0	8.0 - 13.0	193	12.3	10.0 - 15.0
LOWER							
	CENTRAL INCISOR	43	6.0	5.0 - 7.0	77	6.3	5.5 - 7.5
	LATERAL INCISOR	51	6.7	6.0 - 7.5	92	6.6	6.0 - 7.5
	CANINE	88	7.6	7.0 - 9.0	120	8.3	7.0 - 10.0
	THIRD PREMOLAR	93	7.6	7.0 - 9.0	120	8.8	7.0 - 10.0
	FOURTH PREMOLAR	79	7.7	6.5 - 9.0	109	8.9	7.0 - 10.0
	FIRST MOLAR	139	12.3	11.0 - 14.0	186	11.9	10.0 - 13.5
	SECOND MOLAR	152	12.5	10.0 - 14.2	184	11.7	10.0 - 13.5
	THIRD MOLAR	136	11.9	9.0 - 14.0	152	11.1	8.0 - 13.0

*SUMMARY STATISTICS FROM CAMPBELL (1925: 17), SEXES AND LEFT AND RIGHT SIDES POOLED. SAMPLE INCLUDES 105 OF THE SWANPORT SKULLS AS WELL AS 52 SKULLS FROM THE LOWER MURRAY RIVER REGION.

TABLE 2. LARSON SITE ARIKARA DENTAL STATISTICS. *

SEX	TOOTH	Mesio-Distal Diameter N	Mesio-Distal Diameter Mean	Mesio-Distal Diameter Std. Dev.	Mesio-Distal Diameter Range	Bucco-Lingual Diameter N	Bucco-Lingual Diameter Mean	Bucco-Lingual Diameter Std. Dev.	Bucco-Lingual Diameter Range
MALES									
UPPER									
	CENTRAL INCISOR	7	8.6	0.712	7.5 - 9.5	14	7.5	0.478	6.8 - 8.4
	LATERAL INCISOR	8	7.1	0.886	5.6 - 8.1	11	6.7	0.826	4.7 - 7.8
	CANINE	22	8.4	0.409	7.2 - 9.1	32	8.8	0.517	7.9 - 9.7
	THIRD PREMOLAR	23	7.1	0.358	6.3 - 7.7	35	9.6	0.544	8.5 - 10.9
	FOURTH PREMOLAR	27	6.7	0.444	5.7 - 7.5	39	9.3	0.458	8.1 - 10.0
	FIRST MOLAR	30	10.4	0.700	9.0 - 11.5	46	11.9	0.430	11.0 - 12.5
	SECOND MOLAR	38	9.7	0.640	8.2 - 10.6	56	11.9	0.484	10.6 - 12.9
	THIRD MOLAR	38	9.0	0.906	7.4 - 11.4	44	11.2	0.798	8.1 - 12.7
LOWER									
	CENTRAL INCISOR	14	5.0	0.468	4.3 - 5.7	13	6.0	0.386	5.5 - 6.7
	LATERAL INCISOR	17	6.3	0.340	5.9 - 7.0	19	6.2	0.409	5.7 - 7.2
	CANINE	20	7.4	0.544	6.2 - 8.2	24	7.9	0.545	6.3 - 8.8
	THIRD PREMOLAR	38	7.0	0.408	6.0 - 7.8	46	8.0	0.432	7.1 - 8.7
	FOURTH PREMOLAR	39	7.1	0.536	6.0 - 8.4	53	8.3	0.522	7.0 - 9.4
	FIRST MOLAR	39	11.4	0.606	10.4 - 12.7	60	11.1	0.503	9.5 - 12.0
	SECOND MOLAR	43	10.9	0.582	9.7 - 12.1	64	10.6	0.630	9.2 - 11.8
	THIRD MOLAR	44	10.8	1.088	8.6 - 13.2	61	10.5	0.602	8.9 - 12.1
FEMALES									
UPPER									
	CENTRAL INCISOR	25	8.4	0.470	7.4 - 9.1	30	7.4	0.339	6.7 - 8.3
	LATERAL INCISOR	23	7.0	0.467	6.1 - 7.6	27	6.6	0.485	5.7 - 7.8
	CANINE	37	7.9	0.406	7.3 - 9.3	44	8.3	0.478	7.3 - 9.3
	THIRD PREMOLAR	43	7.2	0.470	6.3 - 8.2	49	9.3	0.539	8.1 - 10.9
	FOURTH PREMOLAR	38	6.7	0.443	5.7 - 7.6	38	9.2	0.504	8.1 - 10.2
	FIRST MOLAR	60	10.6	0.704	8.7 - 12.2	70	11.8	0.538	10.1 - 13.0
	SECOND MOLAR	56	9.7	0.536	8.4 - 11.1	60	11.4	0.550	10.4 - 12.5
	THIRD MOLAR	38	9.0	0.776	7.2 - 10.9	42	10.9	0.705	9.4 - 12.0
LOWER									
	CENTRAL INCISOR	27	5.2	0.594	4.2 - 6.4	31	5.8	0.326	5.3 - 6.4
	LATERAL INCISOR	30	6.1	0.562	5.0 - 7.0	34	6.4	0.290	5.6 - 6.9
	CANINE	39	7.1	0.343	6.3 - 7.6	37	7.6	0.538	7.0 - 9.8
	THIRD PREMOLAR	43	6.9	0.442	6.0 - 8.0	47	7.9	0.415	7.1 - 9.0
	FOURTH PREMOLAR	45	7.1	0.458	6.2 - 8.1	51	8.3	0.538	7.3 - 9.7
	FIRST MOLAR	48	11.2	0.564	9.9 - 12.3	64	11.0	0.616	9.7 - 12.5
	SECOND MOLAR	47	10.7	0.677	8.9 - 12.2	61	10.5	0.567	9.1 - 12.1
	THIRD MOLAR	59	10.2	1.179	7.4 - 14.0	59	10.1	0.894	8.0 - 13.2

*DATA COLLECTED BY DR. ANTHONY J. PERZEGIAN, INDIVIDUALS ARE AGED 18 YEARS AND OLDER, LEFT AND RIGHT SIDES ARE POOLED.

They are not particularly noted for non-masticatory use of their teeth nor are their crania particularly robust.

This provokes the question: are certain aspects of cranial architecture functionally related to tooth size or to the extensive use of teeth in masticatory and non-masticatory activities?

Without implying any cause and effect relationship, it seems logical that factors favoring the large teeth of the Australians should also be favoring the massive, robust cranial features. This is especially true in light of their relatively low level of technological development.

The relationship between craniofacial morphology and tooth size is not fully understood. Empirical evidence indicates that contemporary large-toothed populations tend to be more robust cranially than contemporary small-toothed populations, but the exact patterning of this relationship is unknown. This relationship has not been studied extensively probably due in part to the poor preservation of teeth in skeletal samples. The few studies that have been done, for the most part, fail to find any strong correlations between dental and cranial variables (Lombardi 1976; Solow 1966). However, I believe that the statistical techniques employed in these studies were not suitable to adequately deal with the problem. Unfortunately, I have been unable to locate a skeletal sample with adequate dental preservation. Therefore, rather than examining the relationship between tooth size and cranial shape in a single population, this study takes an indirect approach to the problem. If certain aspects of cranial morphology are

related to tooth size or use, they should differ in some interpretable manner between a large-toothed and a small-toothed population.

The majority of craniological investigations in the past have succeeded admirably in isolating group differences in cranial features, however very few of these studies have actually attempted to interpret what these differences may mean. Notable exceptions are Coon (1962), Hylander (1977), Steegman (1970, 1972) and Wolpoff (1968).

This study attempts to put forth some plausible explanations of some of the differences between the Australians and the Arikara in terms of tooth size and the use of those teeth. Not all of the differences between these two groups can be—or should be—interpreted within a framework related to tooth size. Cranial shape is certainly also dependent upon other factors—climatic (Guglielmino-Matessi, et al. 1979), nutritional (Brown 1976), and developmental (Harris 1971), to name a few—unrelated to tooth size or to the use of the teeth.

This analysis examines differences between the groups both in terms of the structural interrelationships among the cranio-facial variables, and in terms of metrical differences between the groups along these structural dimensions.

II. SKELETAL SAMPLES

Murray River Australians

Craniometric data on the Murray River Australians were collected by Dr. W. W. Howells during the course of his worldwide study of human cranial variation (1973) and were very generously provided by him. The specimens are housed at the South Australian Museum in Adelaide. The sample consists of 52 adult males and 49 adult females from the Jarildekald and Warki-Korowalde tribes located near the mouth of the Murray River in South Australia. Six skulls from the nearby Tanganekald tribe were added to fill out the female sample.

The sample is derived from a well defined local population (Howells 1973: 21; Giles 1976: 165). Howells states that "the linguistic and archaeological evidence indicates long-time stability (2000 years?) in the area" (1973: 21). The Jarildekald and Warki-Korowalde were non-circumcising groups who lived on the northern and eastern periphery of Lake Alexandrina. They were culturally distinct from circumcising tribes located to their immediate west, with whom they did not intermarry. The Tanganekald were a linguistically related and intermarrying group located to the south on the shores of the Coorong (Howells 1973: 21; Tindale 1974: 25, 60).

Most of the specimens come from Swanport, an aboriginal cemetery located on the lower Murray River about four miles south of Murray Bridge. The cemetery was discovered in 1911 as a result of construction activities (Stirling 1911: 4-5). Stirling attributes the remains to a

smallpox epidemic dating just prior to the European settlement of Swanport in 1836. Norman Tindale, perhaps the leading authority on Aboriginal anthropology, disagrees. He feels that the cemetery represents a normal accumulation of burials of the Mulbarapi horde of the Jarildekald (quoted by Howells 1973: 21). In either case, the sample dates prior to European contact and represents a fairly well defined breeding population. Stirling (1911: 42) reports that more than 160 individuals were recovered from Swanport, ranging in age from "extreme senility" to children under six months.

Nearby localities yielding additional crania are Lake Albert, Coorong, Port Elliot, Tailem Bend, Milang and Poltalloch (Howells 1978: personal communication).

Ethnohistory. The Jarildekald, Warki-Korowalde and Tanganekald tribes were members of a group of 18 linguistically related and intermarrying tribes collectively known as the Narinjeri (Taplin 1879: 2). Contrary to what Taplin believed, these tribes were not members of a super-tribal "nation." Rather, the non-circumcising tribes in the area called themselves "narinjeri," "we people," to differentiate themselves from the nearby circumcising tribes, "the hardly to be thought of as human beings" (Tindale 1974: 41, 134). The term Narinjeri, as used here, implies the non-circumcising tribes of the lower Murray River and nothing more. In 1840, Taplin estimated that there were about 3,000 Narinjeri (quoted by Stirling 1911: 13). This is probably an underestimation of the population of the area prior to intensive

European contact. Taplin (1879: 44-45) cites native oral traditions of a "terrible disease" coming down the river some 60 years previously, killing them by the hundreds and seriously diminishing the tribes. Taplin (1879:445) states: "the natives always represent that before this scourge arrived they were much more numerous."

The lower Murray River tribes were fairly sedentary, wandering only within the confines of well marked hordal territories or less freely in "the hordal territories of their kinfolk in whose areas they had some rights, derived either from mother or from wife" (Tindale 1974: 60). The tribes were totally exogamous (Taplin 1879: 12). Polgyny was very common, as was infanticide prior to European intervention (Taplin 1879: 10-11, 13-14). In fact, Taplin reports that "more than one-half of the children born fell victim to this atrocious custom" (1879: 13).

The Narinjeri were riverine adapted for the most part, subsisting largely on fish and aquatic birds and plants (Taplin 1879: 41-42; Tinsdale 1974: 61). Their overall level of technology was fairly "primitive." Their stone tools were crude by most standards (see Mulvaney 1969) and they did not have pottery. Their vessels consisted of baskets woven from reeds, the shells of fresh water tortise, or human skulls with the sutures stopped up with resinous gum (Taplin 1879: 42; Massola 1971: 101). However, they did employ a wide variety of wooden implements and nets and fishing lines made from plant fibers. Taplin reports that "a party of them (would) sit round the fire and masticate the fibrous material by the hour" to make the twine from which the nets and lines were made (1879: 41). They also fashioned

canoes out of bark (Taplin 1879: 41) and made extensive use of animal skins (Taplin 1879: 43).

When a death occurred, the body was placed on a low bier and roasted over a low fire for several days until the outer skin blistered. The skin was then removed and the body was rubbed with grease and red ochre and placed in a tree. It remained there for quite some time, sometimes several years, before eventually being buried (Stirling 1911: 11; Taplin 1879: 18-22).

Larson Site Arikara

Craniometric data on the Larson Site Arikara were collected by Paul Lin (1973) utilizing Howells' system of measurement and can be found in the data files at the University of Tennessee Anthropology Department. The sample employed here consists of 54 adult males and 59 adult females. The specimens are housed at the University of Tennessee Anthropology Department.

The Larson Site (39WW2) was located on the east bank of the Missouri River in Walworth County, South Dakota, about five miles south of the confluence of the Grand and Missouri Rivers. The site consisted of a strongly fortified earth lodge village and its associated cemetery (Owsley, Berryman, and Bass 1977: 119). The village was initially excavated by River Basin Survey crews under the direction of Alfred W. Bowers during the summers of 1963 and 1964. Further excavation of the village was carried ont in 1966 by River Basin Survey crews under the direction of J. J. Hoffman. The cemetery

was excavated by University of Kansas crews during the summers of 1966, 1967 and 1968 under the leadership of William M. Bass (Owsley, Berryman and Bass 1977: 119).

A total of 621 human skeletons were recovered from the cemetery area, and an additional 71 skeletons from the village. Most of the latter were found scattered on the earth lodge floors. Demographic and osteological evidence indicates that the individuals recovered from the village area may have died as the result of a raid (Owsley, Berryman and Bass 1977) and that the village was subsequently abandoned.

The Larson Site belongs to the Post-Contact Variant of the Coalescent Tradition (Lehmer 1971). Substantial quantities of European trade goods associated with the burials support this protohistoric affiliation. Jantz (1973: 17) suggests that the site was probably occupied between 1750 and 1785. Owsley's (1975) demographic analysis of the Larson Site indicates that the burials may represent a single breeding generation.

Ethnohistory. The Larson Site and the nearby sites of Rygh (39CA4), Leavenworth (39CO9) and Mobridge (39WW1) represent the northernmost extension of the Arikara prior to the reservation period (Jantz 1977: 164). The Arikara were a Caddoan speaking group, related linguistically to the Pawnee. There is reason to believe that the Arikara moved into the Middle Missouri region from the Central Plains during the time period now known as the Coalescent. This has been supported both archaeologically (Lehmer and Jones 1968) and craniometrically (Jantz 1977).

During the time period represented by the Larson Site, the Arikara were semisedentary horticulturalists, living in fortified earth lodge villages along the upper Missouri River valley. They were also important brokers in an extensive barter network "stretching all the way across the Plains from the Dakotas to New Mexico," dealing in horses and European trade goods (Lehmer and Jones 1968: 86).

Socially, the Arikara were organized into clans. Residential groups consisted of matrilocal extended families and descent was matrilineal. Villages of the post contact period were endogamous and the clans were exogamous. There were two social classes: high ranking "leader" clans and "commoner" clans lacking significant social status. Although there was a tendency towards class endogamy, a great deal of social mobility was also present (Owsley and Jantz 1978; Holder 1970).

The Arikara were fairly sophisticated technologically, employing a wide variety of chipped stone, bone, wood, and ceramic artifacts. With increasing European contact, glass and metal artifacts became more prevalent especially in association with burials (Lehmer 1966, 1971; Lehmer and Jones 1968).

Arikara burials consisted of primary flesh inhumations. The bodies were usually tightly flexed and placed into small circular pits along with a variety of artifacts. Recent research by Ubelaker and Willey (1978) indicates that the Arikara may also have occasionally placed bodies on scaffolds prior to burial.

During the early 1700's, historical sources indicate that the Arikara were a powerful tribe, with an estimated maximum population of

30,000 (Holder 1970: 30). However, European contact during the 1700's and 1800's brought a series of devastating epidemics. Most notable of these were the smallpox epidemics of 1780-81, 1801-02, 1837-38 and 1856 (Lehmer 1971: 172) which virtually decimated the Arikara and brought about a near total cultural collapse.

III. ANALYTICAL METHODS

Variables

A large battery of measurements is required to adequately define cranial shape. There is no standard set of cranial measurements, although the systems proposed by Martin (1928), the Biometric Laboratory (Morant 1927, 1928) and Bass (1971) have been used extensively. The system employed here was developed by Howells (1973: 163-190) for his worldwide study of cranial variation in recent human populations. The measurements and landmarks are precisely defined in the Howells system and are formulated for the expressed purpose of multivariate analysis. Thus no indices or linear combinations of variables are calculated since they would be redundant in a multivariate context. Although the variable set includes many of the standard cranial length, height and breadth measurements, no circumferences, arcs or estimates of cranial capacity are included since these are largely size related variables and give little indication of cranial shape. Howells (1957) feels that size related variation is adequately accounted for by the linear variables.

Certain aspects of cranial shape are defined in the Howells system through angles calculated from chords and subtenses (refer to Figures 1-3 for illustrations of some of these angles). Because of this, Howells has had to more precisely define the location of certain landmarks. For instance, workers often use two different points for basion or for prosthion, depending upon the measurement to be taken. An angle calculated in this manner would be inaccurate since its sides

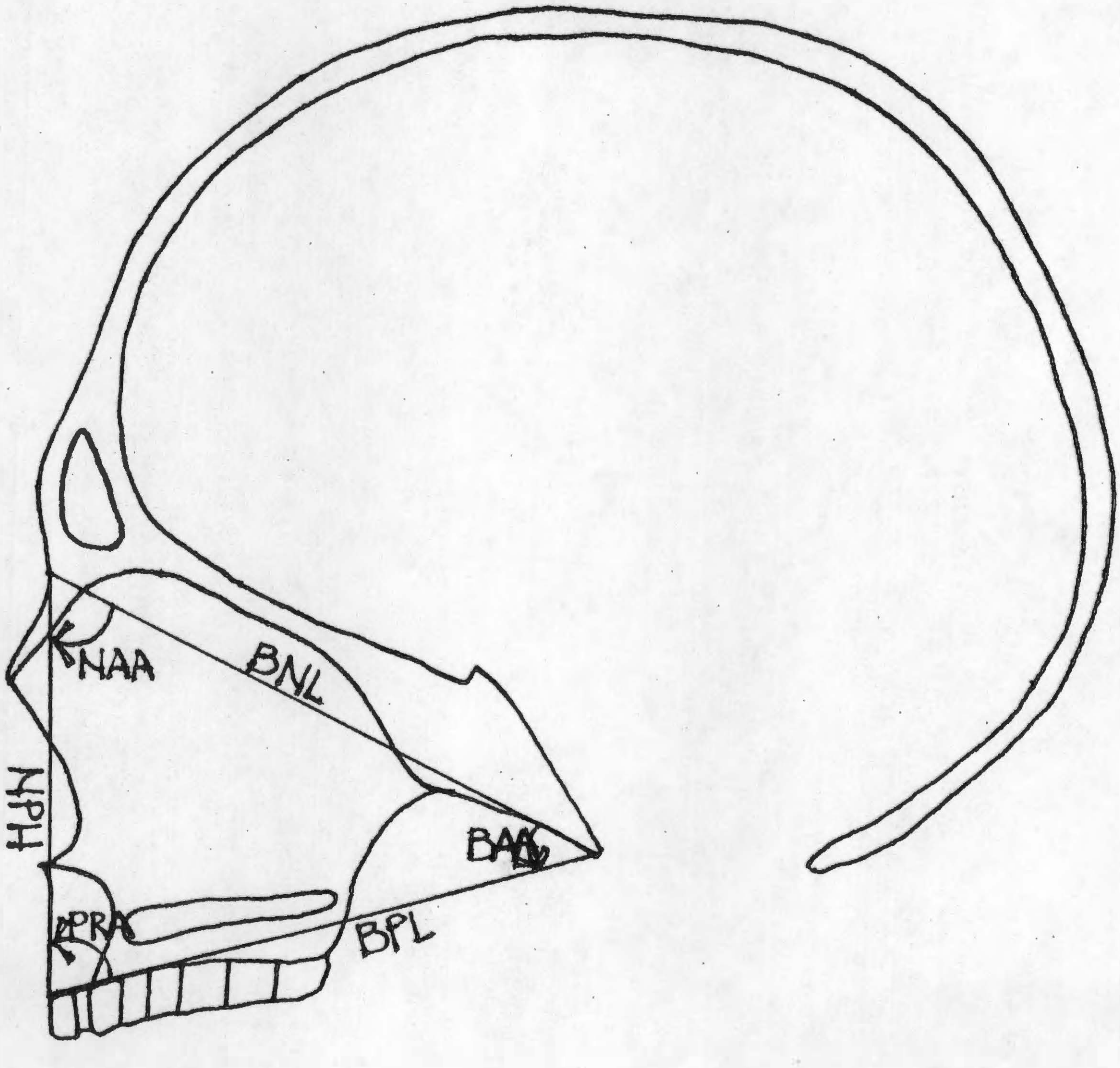

Figure 1. Angles of the Facial Triangle.

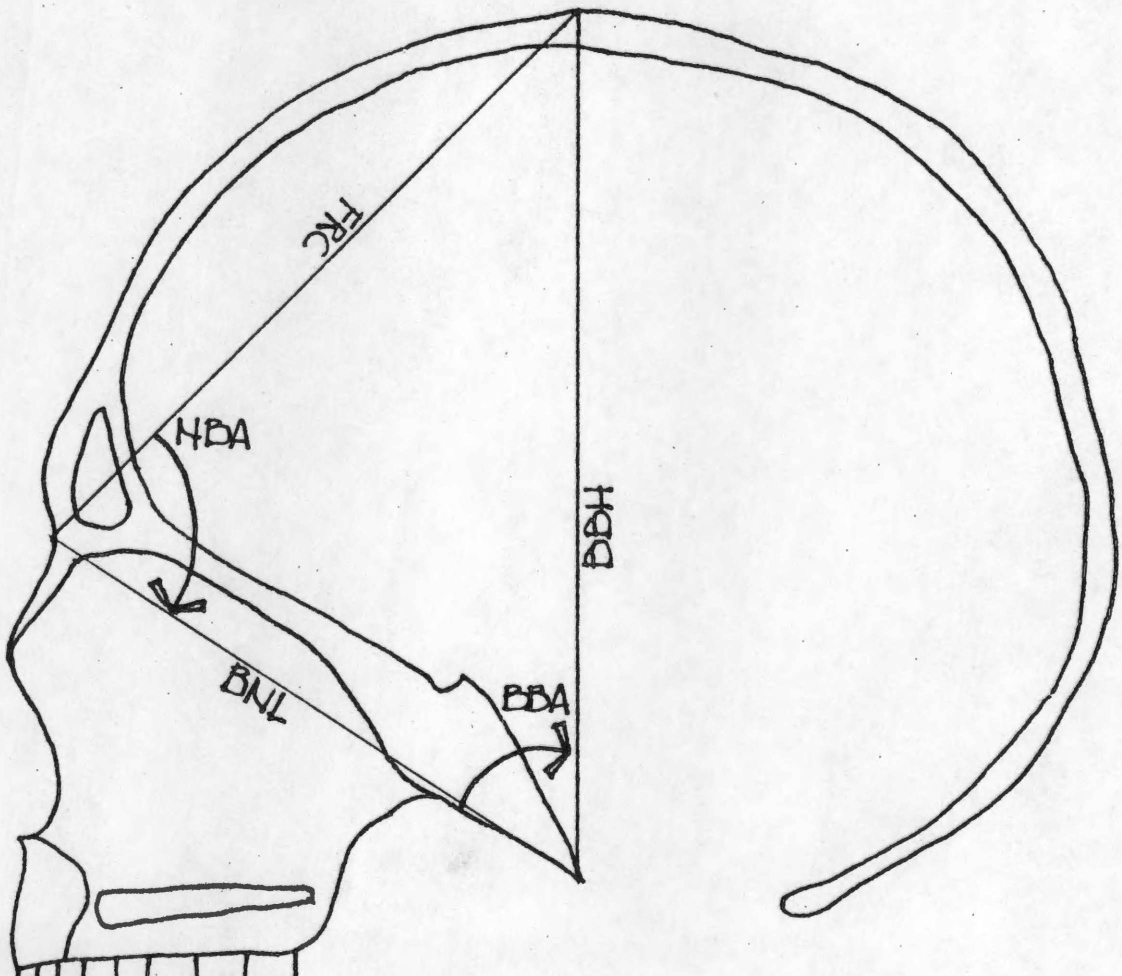

Figure 2. Cranial Height Angles.

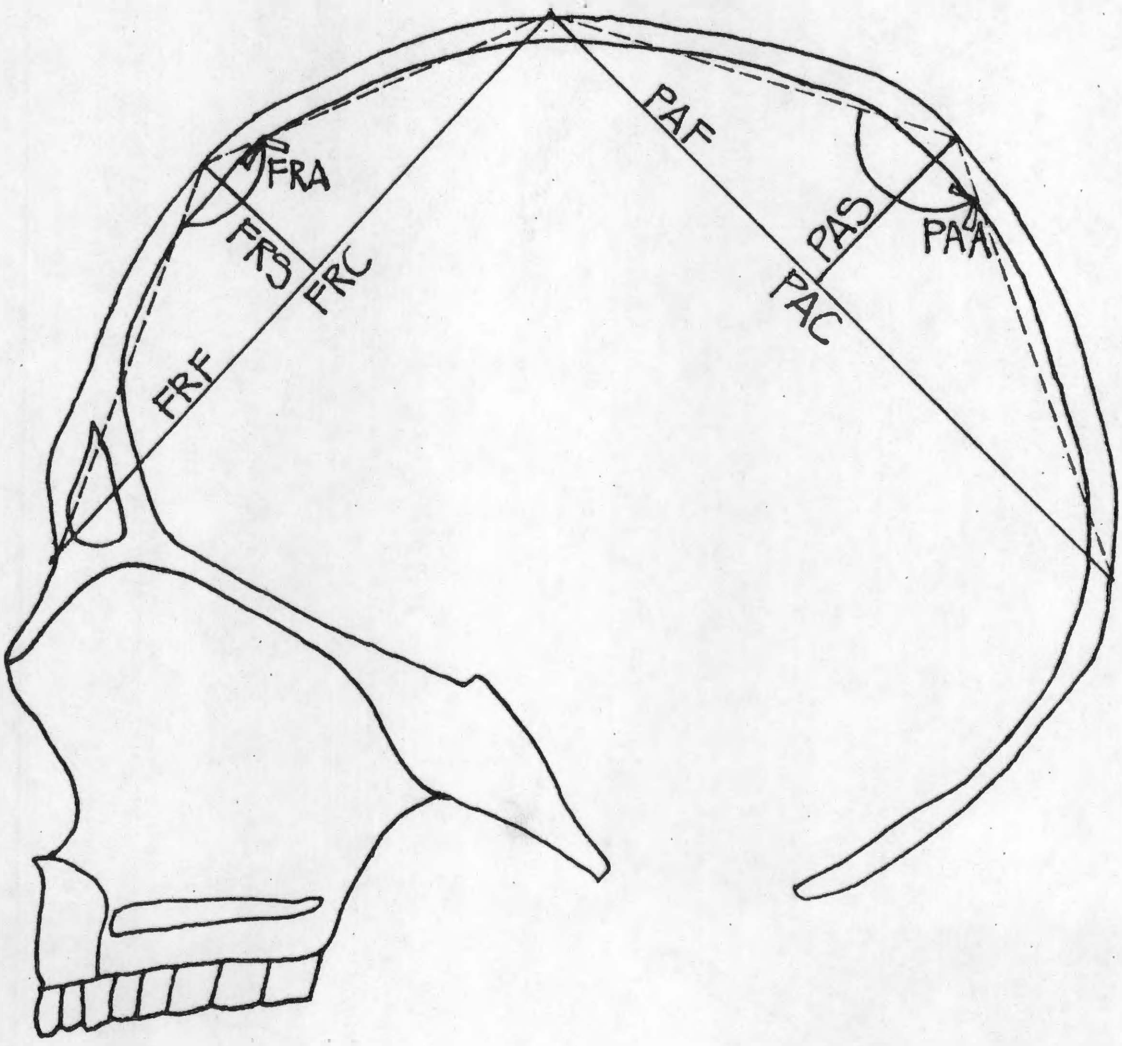

Figure 3. Sagittal Profile Angles.

would not meet at a common point. An inherent aspect of the Howells system is that whenever possible, the measurements are designed to meet at common points. This leads to a coherent, interrelated set of measurements with a minimum amount of overlap and little loss of information.

A convenient feature of the Howells measurement system is the use of a three letter code name for each variable. These code names greatly facilitate the labeling of computer generated material and are utilized throughout this study. (The use of these code names is quite specific and implies that the investigator has taken the measurements precisely as Howells has defined them.) The code names are listed in Table 3 in the order of use. This study uses a subset of 47 of the 70 variables originally defined by Howells.

Descriptive Statistics

Descriptive statistics for each variable were calculated by means of DISTAB, a FORTRAN program written by the author. They are given in Table 4 for the Murray River Australian males, Table 5 for the Murray River Australian females, Table 6 for the Larson Site Arikara males, and Table 7 for the Larson Site Arikara females.

The computational formulas for these statistics are well known and need not be repeated here. The variance and standard deviation are unbiased (n - 1) estimates.

Skewness and kurtosis are measures of the normality of the distribution of a variable. Skewness is an indication of the symmetry

TABLE 3. CODE NAMES FOR VARIABLES IN ORDER OF USE.

CODE	NAME	VARIABLE
1	GOL	GLABELLO-OCCIPITAL LENGTH
2	BNL	BASION-NASION LENGTH
3	BBH	BASION-BREGMA HEIGHT
4	XCB	MAXIMUM CRANIAL BREADTH
5	XFB	MAXIMUM FRONTAL BREADTH
6	STB	BISTEPHANIC BREADTH
7	ZYB	BIZYGOMATIC BREADTH
8	AUB	BIAURICULAR BREADTH
9	BPL	BASION-PROSTHION LENGTH
10	NPH	NASION-PROSTHION LENGTH
11	NLH	NASAL HEIGHT
12	OBH	ORBIT HEIGHT LEFT
13	OBB	ORBIT BREADTH LEFT
14	NLB	NASAL BREADTH
15	MAB	PALATE BREADTH
16	MDH	MASTOID HEIGHT
17	ZMB	BIMAXILLARY BREADTH
18	SSS	ZYGOMAXILLARY SUBTENSE
19	FMB	BIFRONTAL BREADTH
20	NAS	NASIO-FRONTAL SUBTENSE
21	EKB	BIORBITAL BREADTH
22	DKB	INTERORBITAL BREADTH
23	NDS	NASO-DACRYAL SUBTENSE
24	WMH	CHEEK HEIGHT
25	SOS	SUPRAORBITAL PROJECTION
26	GLS	GLABELLA PROJECTION
27	FRC	NASION-BREGMA CHORD
28	FRS	NASION-BREGMA SUBTENSE
29	FRF	NASION SUBTENSE FRACTION
30	PAC	BREGMA-LAMBDA CHORD
31	PAS	BREGMA-LAMBDA SUBTENSE
32	PAF	BREGMA-SUBTENSE FRACTION
33	NAR	NASION RADIUS
34	SSR	SUBSPINALE RADIUS
35	PRR	PROSTHION RADIUS
36	ZOR	ZYGOORBITALE RADIUS
37	ZMR	ZYGOMAXILLARE RADIUS
38	NAA	NASION ANGLE, BA-PR
39	PRA	PROSTHION ANGLE, NA-BA
40	BAA	BASION ANGLE, NA-PR
41	NBA	NASION ANGLE, BA-BR
42	BBA	BASION ANGLE, NA-BR
43	SSA	ZYGOMAXILLARY ANGLE
44	NFA	NASIO-FRONTAL ANGLE
45	NDA	NASO-DACRYAL ANGLE
46	FRA	FRONTAL ANGLE
47	PAA	PARIETAL ANGLE

TABLE 4. DESCRIPTIVE STATISTICS OF THE MURRAY RIVER AUSTRALIAN MALES.

	VARIABLE	CODE NAME	N	MEAN	VARIANCE	STD. DEV.	RANGE	SKEWNESS	KURTOSIS
1	GLAB-OCC L	GOL	52	190.3	29.4	5.4	179.0 - 201.0	0.043	-0.744
2	BAS-NAS L	BNL	52	102.0	11.4	3.4	96.0 - 109.0	0.313	-0.304
3	BAS-BREG HT	BBH	52	129.6	28.8	5.4	120.0 - 143.0	0.298	-0.641
4	MAX BR	XCB	52	131.9	26.1	5.1	124.0 - 144.0	0.603	-0.291
5	MAX FRONT BR	XFB	52	110.1	18.0	4.2	99.0 - 119.0	-0.101	-0.134
6	BISTEPHANIC	STB	52	101.3	39.1	6.3	90.0 - 116.0	0.223	-0.741
7	BIZYG BR	ZYB	52	136.8	17.4	4.2	127.0 - 146.0	0.117	-0.379
8	BIAURIC BR	AUB	52	120.1	17.4	4.2	109.0 - 128.0	-0.388	0.138
9	BAS-PROSTH	BPL	52	105.5	20.0	4.5	97.0 - 114.0	-0.053	-0.996
10	NAS-PROSTH	NPH	52	64.8	17.3	4.2	56.0 - 73.0	0.031	-0.424
11	NASAL HT	NLH	52	49.7	7.2	2.7	43.0 - 56.0	0.062	-0.222
12	ORBIT HT	OBH	52	33.5	3.7	1.9	29.0 - 39.0	0.237	0.348
13	ORBIT BR	OBB	52	41.9	2.3	1.5	38.0 - 45.0	-0.108	-0.135
14	NASAL BR	NLB	52	27.9	3.0	1.7	25.0 - 34.0	0.612	1.487
15	PALATE BR	MAB	52	66.9	11.0	3.3	61.0 - 76.0	0.747	0.668
16	MASTOID L	MDH	52	29.9	10.1	3.2	22.0 - 37.0	0.258	-0.004
17	BIMAXILLARY	ZMB	52	98.3	16.5	4.1	88.0 - 109.0	0.377	0.773
18	ZYGOMAX SUB	SSS	52	24.1	4.7	2.2	20.0 - 28.0	0.067	-0.982
19	BIFRONTAL	FMB	52	102.4	12.7	3.6	93.0 - 110.0	-0.536	0.274
20	NAS-FR SUBT	NAS	52	17.5	6.5	2.6	11.0 - 23.0	-0.266	0.071
21	BIORBITAL	EKB	52	102.0	11.1	3.3	94.0 - 111.0	0.249	0.373
22	INTERORB	DKB	52	21.7	4.3	2.1	17.0 - 26.0	0.031	-0.443
23	NAS-DAC SUB	NDS	52	11.5	1.5	1.2	9.0 - 14.0	0.436	-0.454
24	CHEEK HT	WMH	52	21.2	4.6	2.1	16.0 - 27.0	0.212	0.436
25	SUPRAORB PR	SOS	52	7.4	1.1	1.1	5.0 - 10.0	-0.049	-0.444
26	GLABELLA PR	GLS	52	5.4	0.9	1.0	3.0 - 7.0	-0.264	-0.086
27	NAS-BREG C	FRC	52	111.9	14.0	3.7	104.0 - 121.0	0.232	-0.298
28	NAS-BREG SUB	FRS	52	25.2	6.3	2.5	20.0 - 32.0	0.325	-0.017
29	NAS FRACTION	FRF	52	50.2	11.9	3.5	43.0 - 61.0	0.494	0.637
30	BREG-LAM C	PAC	52	116.6	22.7	4.8	108.0 - 130.0	0.321	0.129
31	BREG-LAM SUB	PAS	52	23.9	5.3	2.3	17.0 - 28.0	-0.407	0.336
32	BREG FRACT	PAF	52	58.4	15.5	3.9	49.0 - 68.0	-0.142	-0.074
33	NASION RAD	NAR	52	96.1	10.0	3.2	91.0 - 104.0	0.541	-0.307
34	SUBSPIN RAD	SSR	52	100.5	13.3	3.6	93.0 - 108.0	-0.119	-0.484
35	PROSTH RAD	PRR	52	108.5	17.0	4.1	97.0 - 117.0	-0.360	-0.038
36	ZYGOORB RAD	ZOR	52	82.8	8.3	2.9	77.0 - 90.0	0.418	0.283
37	ZYGOMAX RAD	ZMR	52	77.3	8.5	2.9	72.0 - 84.0	0.091	-0.670
38	NAS ANG B-P	NAA	52	74.8	10.5	3.2	69.0 - 86.0	0.740	1.283
39	PROSTH ANG	PRA	52	68.9	9.4	3.1	61.0 - 75.0	-0.355	-0.232
40	BAS ANG N-P	BAA	52	36.3	5.1	2.3	32.0 - 41.0	-0.009	-0.740
41	NAS ANG B-B	NBA	52	74.3	10.1	3.2	67.0 - 80.0	-0.309	-0.547
42	BAS ANG N-B	BBA	52	56.2	4.0	2.0	51.0 - 62.0	0.283	0.852
43	ZYGOMAX ANG	SSA	52	127.8	18.4	4.3	119.0 - 135.0	-0.193	-0.915
44	NAS-FR ANG	NFA	52	142.2	22.8	4.8	132.0 - 153.0	0.308	-0.223
45	NAS-DAC ANG	NDA	52	88.6	72.5	8.5	71.0 - 105.0	0.209	-0.611
46	FRONTAL ANG	FRA	52	131.1	13.3	3.6	121.0 - 140.0	-0.194	0.051
47	PARIETAL ANG	PAA	52	135.4	10.0	3.2	130.0 - 146.0	0.729	0.457

TABLE 5. DESCRIPTIVE STATISTICS OF THE MURRAY RIVER AUSTRALIAN FEMALES.

VARIABLE		CODE NAME	N	MEAN	VARIANCE	STD. DEV.	RANGE	SKEWNESS	KURTOSIS
1	GLAB-OCC L	GOL	49	181.1	40.5	6.4	169.0 - 196.0	0.089	-0.651
2	BAS-NAS L	BNL	49	96.2	9.9	3.1	89.0 - 105.0	0.144	0.092
3	BAS-BREG HT	BBH	49	123.5	21.9	4.7	114.0 - 136.0	0.404	-0.061
4	MAX BR	XCB	49	127.5	21.9	4.7	117.0 - 138.0	-0.002	0.199
5	MAX FRONT BR	XFB	49	106.2	12.3	3.5	96.0 - 113.0	-0.663	0.410
6	BISTEPHANIC	STB	49	100.2	27.0	5.2	90.0 - 113.0	0.013	-0.226
7	BIZYG BR	ZYB	49	125.8	21.8	4.7	116.0 - 138.0	0.276	-0.240
8	BIAURIC BR	AUB	49	113.2	19.8	4.5	103.0 - 124.0	0.200	-0.131
9	BAS-PROSTH	BPL	49	100.4	14.8	3.8	92.0 - 109.0	0.100	-0.576
10	NAS-PROSTH	NPH	49	61.1	15.6	4.0	53.0 - 68.0	-0.516	-0.413
11	NASAL HT	NLH	49	46.5	6.5	2.5	40.0 - 52.0	-0.177	-0.209
12	ORBIT HT	OBH	49	33.1	3.5	1.9	29.0 - 37.0	-0.035	-0.128
13	ORBIT BR	OBB	49	40.0	2.3	1.5	35.0 - 43.0	-0.331	1.153
14	NASAL BR	NLB	49	26.2	2.3	1.5	23.0 - 29.0	-0.423	-0.742
15	PALATE BR	MAB	49	62.6	7.5	2.7	58.0 - 69.0	0.304	-0.712
16	MASTOID L	MDH	49	24.7	6.7	2.6	19.0 - 29.0	-0.447	-0.753
17	BIMAXILLARY	ZMB	49	91.6	21.3	4.6	83.0 - 101.0	0.166	-0.787
18	ZYGOMAX SUB	SSS	49	23.2	6.1	2.5	19.0 - 29.0	0.230	-0.207
19	BIFRONTAL	FMB	49	97.7	13.9	3.7	90.0 - 108.0	0.327	0.435
20	NAS-FR SUBT	NAS	49	17.2	3.9	2.0	13.0 - 21.0	-0.021	-0.978
21	BIORBITAL	EKB	49	97.5	11.0	3.3	91.0 - 105.0	0.496	0.114
22	INTERORB	DKB	49	20.9	3.1	1.8	16.0 - 25.0	-0.145	0.877
23	NAS-DAC SUB	NDS	49	10.2	1.6	1.2	7.0 - 13.0	-0.117	-0.163
24	CHEEK HT	WMH	49	19.5	4.3	2.1	16.0 - 24.0	0.306	-0.623
25	SUPRAORB PR	SOS	49	6.2	1.8	1.3	4.0 - 9.0	0.125	-0.993
26	GLABELLA PR	GLS	49	4.0	1.1	1.0	2.0 - 6.0	0.306	-0.270
27	NAS-BREG C	FRC	49	105.9	18.1	4.3	95.0 - 114.0	-0.193	-0.255
28	NAS-BREG SUB	FRS	49	25.3	3.8	2.0	19.0 - 29.0	-0.782	1.297
29	NAS FRACTION	FRF	49	46.5	9.4	3.1	39.0 - 52.0	-0.680	0.124
30	BREG-LAM C	PAC	49	110.3	36.6	6.0	98.0 - 121.0	-0.185	-0.733
31	BREG-LAM SUB	PAS	49	22.6	5.3	2.3	18.0 - 28.0	-0.151	-0.361
32	BREG FRACT	PAF	49	55.0	12.1	3.5	49.0 - 64.0	0.353	0.077
33	NASION RAD	NAR	49	91.1	7.7	2.8	86.0 - 99.0	0.166	-0.275
34	SUBSPIN RAD	SSR	49	95.4	6.1	2.5	90.0 - 101.0	0.066	-0.437
35	PROSTH RAD	PRR	49	103.6	10.7	3.3	97.0 - 111.0	0.077	-0.602
36	ZYGOORB RAD	ZOR	49	79.1	8.2	2.9	73.0 - 85.0	-0.084	-0.765
37	ZYGOMAX RAD	ZMR	49	73.1	8.0	2.8	68.0 - 78.0	0.117	-0.862
38	NAS ANG B-P	NAA	49	75.8	15.2	3.9	66.0 - 87.0	0.045	0.580
39	PROSTH ANG	PRA	49	68.1	12.2	3.5	60.0 - 76.0	-0.098	-0.197
40	BAS ANG N-P	BAA	49	36.1	5.8	2.4	31.0 - 42.0	-0.132	-0.378
41	NAS ANG B-B	NBA	49	75.2	5.7	2.4	70.0 - 81.0	0.151	-0.243
42	BAS ANG N-B	BBA	49	56.0	5.2	2.3	52.0 - 62.0	0.352	-0.024
43	ZYGOMAX ANG	SSA	49	126.2	26.9	5.2	113.0 - 138.0	-0.331	0.031
44	NAS-FR ANG	NFA	49	141.1	15.0	3.9	135.0 - 148.0	0.119	-1.258
45	NAS-DAC ANG	NDA	49	91.8	67.2	8.2	77.0 - 115.0	0.781	1.083
46	FRONTAL ANG	FRA	49	128.3	10.5	3.2	123.0 - 138.0	0.828	0.588
47	PARIETAL ANG	PAA	49	135.4	8.9	3.0	129.0 - 142.0	0.197	-1.329

TABLE 6. DESCRIPTIVE STATISTICS OF THE LARSON SITE ARIKARA MALES.

	VARIABLE	CODE NAME	N	MEAN	VARIANCE	STD. DEV.	RANGE	SKEWNESS	KURTOSIS
1	GLAB-OCC L	GOL	54	181.7	32.7	5.7	171.0 - 195.0	0.308	-0.826
2	BAS-NAS L	BNL	54	103.5	12.4	3.5	97.0 - 111.0	-0.024	-0.569
3	BAS-BREG HT	BBH	54	134.3	16.8	4.1	125.0 - 143.0	0.042	-0.710
4	MAX BR	XCB	54	140.4	12.4	3.5	133.0 - 151.0	0.440	0.067
5	MAX FRONT BR	XFB	54	116.4	12.5	3.5	109.0 - 124.0	0.034	-0.817
6	BISTEPHANIC	STB	54	109.9	24.8	5.0	93.0 - 118.0	-0.729	0.915
7	BIZYG BR	ZYB	54	140.1	18.1	4.3	130.0 - 148.0	-0.162	-0.650
8	BIAURIC BR	AUB	54	129.6	17.3	4.2	118.0 - 138.0	-0.169	-0.304
9	BAS-PROSTH	BPL	54	100.6	17.6	4.2	92.0 - 114.0	0.732	1.734
10	NAS-PROSTH	NPH	54	73.8	15.0	3.9	68.0 - 82.0	0.504	-0.646
11	NASAL HT	NLH	54	55.4	6.1	2.5	50.0 - 61.0	0.149	-0.050
12	ORBIT HT	OBH	54	35.6	3.7	1.9	31.0 - 40.0	-0.030	-0.278
13	ORBIT BR	OBB	54	40.7	2.3	1.5	38.0 - 44.0	0.029	-0.747
14	NASAL BR	NLB	54	26.0	2.1	1.5	23.0 - 30.0	0.078	-0.141
15	PALATE BR	MAB	54	66.1	5.2	2.3	60.0 - 70.0	-0.424	-0.087
16	MASTOID L	MDH	54	29.3	7.5	2.7	23.0 - 35.0	0.160	-0.511
17	BIMAXILLARY	ZMB	54	102.9	16.2	4.0	95.0 - 112.0	0.172	-0.558
18	ZYGOMAX SUB	SSS	54	25.9	5.6	2.4	21.0 - 31.0	-0.013	-0.598
19	BIFRONTAL	FMB	54	100.3	9.9	3.1	93.0 - 106.0	-0.525	-0.271
20	NAS-FR SUBT	NAS	54	17.9	5.0	2.2	13.0 - 23.0	-0.041	-0.001
21	BIORBITAL	EKB	54	99.9	9.0	3.0	92.0 - 105.0	-0.627	-0.107
22	INTERORB	DKB	54	21.3	4.0	2.0	18.0 - 27.0	0.479	0.320
23	NAS-DAC SUB	NDS	54	10.8	1.4	1.2	8.0 - 13.0	-0.193	-0.274
24	CHEEK HT	WMH	54	24.6	3.6	1.9	21.0 - 28.0	-0.132	-0.474
25	SUPRAORB PR	SOS	54	6.8	1.0	1.0	5.0 - 9.0	0.577	0.252
26	GLABELLA PR	GLS	54	3.4	1.3	1.2	1.0 - 7.0	0.703	0.719
27	NAS-BREG C	FRC	54	112.3	11.9	3.5	104.0 - 119.0	-0.296	-0.209
28	NAS-BREG SUB	FRS	54	23.3	2.8	1.7	20.0 - 27.0	0.340	-0.191
29	NAS FRACTION	FRF	54	50.5	12.9	3.6	44.0 - 59.0	0.212	-0.362
30	BREG-LAM C	PAC	54	109.7	27.4	5.2	98.0 - 124.0	0.458	0.269
31	BREG-LAM SUB	PAS	54	24.1	6.9	2.6	19.0 - 32.0	0.429	1.645
32	BREG FRACT	PAF	54	54.2	47.3	6.9	34.0 - 69.0	-0.264	0.097
33	NASION RAD	NAR	54	94.3	12.0	3.5	86.0 - 102.0	0.010	-0.251
34	SUBSPIN RAD	SSR	54	96.3	11.8	3.4	90.0 - 105.0	0.492	-0.133
35	PROSTH RAD	PRR	54	101.7	13.2	3.6	94.0 - 113.0	0.672	0.323
36	ZYGOORB RAD	ZOR	54	78.1	6.9	2.6	73.0 - 85.0	0.518	0.049
37	ZYGOMAX RAD	ZMR	54	70.4	8.5	2.9	64.0 - 77.0	-0.008	-0.053
38	NAS ANG B-P	NAA	54	66.2	6.9	2.6	61.0 - 74.0	0.324	0.414
39	PROSTH ANG	PRA	54	70.4	8.1	2.8	65.0 - 76.0	0.009	-0.741
40	BAS ANG N-P	BAA	54	41.9	8.0	2.8	37.0 - 49.0	0.640	-0.043
41	NAS ANG B-B	NBA	54	76.4	7.6	2.8	69.0 - 83.0	-0.224	-0.045
42	BAS ANG N-B	BBA	54	54.0	5.8	2.4	49.0 - 61.0	0.197	-0.015
43	ZYGOMAX ANG	SSA	54	126.1	19.8	4.5	117.0 - 136.0	0.121	-0.629
44	NAS-FR ANG	NFA	54	140.4	16.0	4.0	131.0 - 150.0	0.142	-0.331
45	NAS-DAC ANG	NDA	54	88.8	66.5	8.2	73.0 - 107.0	0.134	-0.278
46	FRONTAL ANG	FRA	54	134.0	7.3	2.7	129.0 - 140.0	-0.087	-2.019
47	PARIETAL ANG	PAA	54	131.8	15.3	3.9	118.0 - 141.0	-0.407	1.779

TABLE 7. DESCRIPTIVE STATISTICS OF THE LARSON SITE ARIKARA FEMALES.

VARIABLE	CODE NAME	N	MEAN	VARIANCE	STD. DEV.	RANGE	SKEWNESS	KURTOSIS
1 GLAB-OCC L	GOL	59	173.8	29.5	5.5	163.0 - 188.0	0.029	-0.497
2 BAS-NAS L	BNL	59	98.4	16.5	4.1	90.0 - 107.0	-0.028	-0.494
3 BAS-BREG HT	BBH	59	128.7	29.1	5.4	113.0 - 141.0	-0.488	0.250
4 MAX BR	XCB	59	136.2	18.7	4.3	127.0 - 148.0	0.093	0.009
5 MAX FRONT BR	XFB	59	112.4	16.4	4.1	101.0 - 123.0	-0.269	0.761
6 BISTEPHANIC	STB	59	106.6	24.9	5.0	95.0 - 123.0	-0.343	0.864
7 BIZYG BR	ZYB	59	129.7	20.8	4.6	115.0 - 142.0	-0.372	1.534
8 BIAURIC BR	AUB	59	123.0	21.8	4.7	111.0 - 133.0	-0.542	0.229
9 BAS-PROSTH	BPL	59	97.4	13.1	3.6	89.0 - 108.0	0.133	0.072
10 NAS-PROSTH	NPH	59	69.3	12.3	3.5	61.0 - 78.0	0.228	-0.294
11 NASAL HT	NLH	59	51.0	5.1	2.2	46.0 - 57.0	-0.058	-0.009
12 ORBIT HT	OBH	59	35.2	3.0	1.7	31.0 - 39.0	0.074	-0.232
13 ORBIT BR	OBB	59	39.5	2.5	1.6	36.0 - 43.0	0.123	-0.804
14 NASAL BR	NLB	59	25.5	2.7	1.6	21.0 - 30.0	0.201	0.269
15 PALATE BR	MAB	59	63.3	8.0	2.8	58.0 - 69.0	0.140	-0.280
16 MASTOID L	MDH	59	26.6	6.8	2.6	21.0 - 33.0	0.126	-0.152
17 BIMAXILLARY	ZMB	59	96.8	16.6	4.1	87.0 - 105.0	-0.107	-0.270
18 ZYGOMAX SUB	SSS	59	24.6	5.4	2.3	20.0 - 31.0	0.220	0.072
19 BIFRONTAL	FMB	59	96.6	10.7	3.3	88.0 - 104.0	-0.364	0.592
20 NAS-FR SUBT	NAS	59	17.1	4.4	2.1	12.0 - 21.0	0.193	-0.526
21 BIORBITAL	EKB	59	96.3	9.3	3.0	88.0 - 103.0	-0.252	0.424
22 INTERORB	DKB	59	20.2	2.3	1.5	17.0 - 23.0	0.247	-0.773
23 NAS-DAC SUB	NDS	59	10.2	1.5	1.2	8.0 - 12.0	-0.109	-1.044
24 CHEEK HT	WMH	59	22.3	3.5	1.9	19.0 - 27.0	0.410	-0.006
25 SUPRAORB PR	SOS	59	4.8	0.6	0.8	3.0 - 7.0	0.296	-0.029
26 GLABELLA PR	GLS	58	1.9	0.9	0.9	1.0 - 4.0	0.756	-0.426
27 NAS-BREG C	FRC	59	108.3	16.2	4.0	97.0 - 118.0	-0.523	0.705
28 NAS-BREG SUB	FRS	59	24.0	5.2	2.3	19.0 - 28.0	-0.157	-0.210
29 NAS FRACTION	FRF	59	47.8	9.9	3.1	40.0 - 58.0	0.248	0.962
30 BREG-LAM C	PAC	59	105.5	25.2	5.0	98.0 - 122.0	0.744	0.851
31 BREG-LAM SUB	PAS	59	22.6	6.0	2.4	17.0 - 29.0	0.196	-0.184
32 BREG FRACT	PAF	59	52.6	11.6	3.4	43.0 - 60.0	-0.225	0.161
33 NASION RAD	NAR	59	85.9	13.8	3.7	80.0 - 98.0	-0.300	0.093
34 SUBSPIN RAD	SSR	59	92.0	12.2	3.5	82.0 - 104.0	0.247	2.257
35 PROSTH RAD	PRR	59	98.1	13.3	3.7	89.0 - 110.0	-0.006	1.663
36 ZYGOORB RAD	ZOR	59	75.8	9.3	3.1	68.0 - 84.0	-0.058	0.357
37 ZYGOMAX RAD	ZMR	59	67.6	11.2	3.3	61.0 - 75.0	0.083	-0.341
38 NAS ANG B-P	NAA	59	67.9	7.4	2.7	63.0 - 76.0	0.847	0.515
39 PROSTH ANG	PRA	59	69.6	9.3	3.1	58.0 - 75.0	-0.716	1.986
40 BAS ANG N-P	BAA	59	40.9	5.2	2.3	35.0 - 46.0	0.135	-0.446
41 NAS ANG B-B	NBA	59	76.4	5.3	2.3	70.0 - 82.0	-0.352	0.974
42 BAS ANG N-B	BBA	59	54.7	4.9	2.2	50.0 - 61.0	0.635	0.411
43 ZYGOMAX ANG	SSA	59	125.7	20.6	4.5	115.0 - 137.0	0.053	-0.237
44 NAS-FR ANG	NFA	59	140.6	16.6	4.1	133.0 - 151.0	-0.050	-0.822
45 NAS-DAC ANG	NDA	59	88.9	55.8	7.5	76.0 - 107.0	0.225	-0.553
46 FRONTAL ANG	FRA	59	131.2	13.3	3.7	125.0 - 139.0	0.345	-0.776
47 PARIETAL ANG	PAA	59	133.1	13.4	3.7	121.0 - 141.0	-0.356	0.463

of the distribution around the mean and kurtosis is an indication of whether the distribution is peaked or flat. A normally distributed variable will have skewness and kurtosis values of zero.

Principal Components Analysis

When a large number of measurements are taken on a cranial sample, there is bound to be some overlapping information. For example, auricular height and basion-bregma height contain similar information: one measures the height of the cranial vault above the Frankfort Horizontal and the other measures the height of the vault above the cranial base. This "redundancy" among the variables is termed "correlation." Other sources of correlation among the variables are associations related to structural or biological effects.

Principal components analysis transforms a data matrix into a series of uncorrelated (orthogonal) components, each of which accounts for a portion of the correlation among the variables. The criterion for extraction of a component is to "explain" as much of the correlation remaining in the matrix while retaining orthogonality with the previous components. The components are thus ordered in importance, first to last. A measure of the importance of a component is its eigenvalue, from which can be calculated the amount of the total variation (correlation) explained by that component (Gorsuch 1974: 89).

In theory, as many components can be extracted from a data matrix as there are variables (or individuals in the sample, whichever is smaller) but this is seldom necessary. Usually, the significant

correlation in the sample can be accounted for by a relatively small number of components; specifically, the "principal" components are usually those with eigenvalues greater than 1.0 (see Tatsuoka 1971: 147). Principal components analysis is thus a technique that reduces a large number of variables to a smaller number of orthogonal components while retaining virtually all of the original information.

A measure of the amount of the total variation of a measurement accounted for by the set of principal components is its "communality." This can be thought of as the amount of information that a variable "holds in common" with the rest of the variables as opposed to information it holds independent of the rest. This independent information is usually not of interest in this context because it is unrelated to the common structuring of the variables.

Once the components have been extracted, those with eigenvalues greater than 1.0 are usually rotated in multidimensional space to facilitate their interpretation. This rotation is somewhat difficult to understand conceptually, however an excellent visual presentation of this matter is given by Veldman (1967: 206-217). There are a number of rotational techniques, each of which imposes a different set of constraints on the solution (see Harman 1976). The rotational technique applied here is the VARIMAX solution (Kaiser 1958). It is the rotational technique most commonly applied to biological data. VARIMAX rotation retains the orthogonality of the components while maximizing the variation within each component. This has the effect of emphasizing the effects of a small number of variables on a component

while diminishing the effects of the other variables. Thus those variables with coefficients ("loadings") approaching 1.0 are those that contribute the most information to the component, while those with loadings approaching 0.0 contribute little information. From the pattern of loadings on a component, the biological or functional "meaning" of a component can be determined.

It should be emphasized that the biological reality of these components is not assured. The pattern of loadings on a component is dependent upon the set of original measurements, the accuracy of these measurements and the number of components subject to rotation (Howells 1973: 129). Usually, only those components with eigenvalues greater than 1.0 are rotated. This is grounded in common practice and has an intuitive justification in that components with eigenvalues less than 1.0 contain less information than a single original variable. The pattern of loadings will change with the number of components rotated, however the interpretation of the more important components should not change substantially.

Some computational details. It is beyond the scope of this work to present a full mathematical derivation of principal components analysis. Excellent discussions of this matter can be found in Cooley and Lohnes (1971), Veldman (1967) or Harman (1976).

Principal components were extracted for each group by the PA1 option of the SPSS FACTOR procedure (Nie, et al. 1975). This procedure extracts the principal components from the correlation matrix rather

than the variance-covariance matrix (see Zegura (1978) for a discussion of differences resulting from this approach).

The first 10 components for each group were subjected to VARIMAX rotation using the VORS program from Veldman (1967: 213-218). Only 10 components were rotated (rather than all the components with eigenvalues greater than 1.0) to simplify later comparisons of group component structures.

Component Structure Comparison

The set of principal components for a population may be referred to as the "component structure" of the population. The component structures of two populations may be compared by a rotational technique developed by Kaiser, Hunka and Bianchini (1971).

The correlation coefficient between any two variables can be thought of as the cosine between the vectors described by those variables in multidimensional space (Harman 1976: 63). Since the principal components are all orthogonal to each other (i.e., have correlation coefficients of 0.0) their vectors are all at right angles to each other.

The Kaiser technique rotates the set of component vectors for one population into maximum contiguity with the set of component vectors of the other population and then measures the cosines between the vectors. The resulting matrix of cosines can be thought of as the correlation matrix between all possible pairs of principal components of the two populations. If the component structures of the two

populations are identical, the component vectors should line up perfectly. This would result in a matrix of cosines with a single 1.0 in each column, the rest of the column being made up of 0.0's. This would indicate that each principal component from the first population correlates perfectly with a single principal component from the second population and is totally uncorrelated with any other component in the second population.

The component structures of the populations under study were compared, sexes separate, by RELATE, a FORTRAN program written by Veldman (1967: 236-244) following the matrix formulas of Kaiser, Hunka and Bianchini (1971).

The program requires the input of the component matrices for the two populations (designated A and B). These matrices are normalized upon input (setting their row sums of squares equal to 1.0). The matrix of cosines (designated C), expressing the best possible fit between the A and B matrices, is then calculated.

The B matrix is then postmultiplied by the matrix of cosines (C), rotating it into maximum contiguity with A. This "new B" matrix is designated Q. If the component structures of the two populations are identical, Q should be identical to A. Matrix A is then postmultiplied by the transpose of Q and the diagonal of the resulting matrix is extracted. The diagonal of the product of a matrix postmultiplied by its transpose contains row sums of squares (Veldman 1967: 160). Since the matrices were normalized upon input, the elements of the diagonal of this product matrix should all equal 1.0 if A and Q are identical.

This diagonal ("test vector") thus measures how similarly each variable behaves in the two populations. The values can range between 0.0 and 1.0. The closer the value is to 1.0 the more similarly the variable behaves in the two populations.

Thus the populations can be compared both in terms of similarity of component structures (by the matrix of cosines) and in terms of how similarly the variables behave in the two populations (by the diagonal test vector).

Analysis of Principal Component Scores

Another way of making group comparisons is to examine differences between groups on component scores derived from the common correlation matrix. This procedure is somewhat analogous to an alternative means of calculating a generalized distance statistic proposed by Goodman (1972, 1974).

A pooled within-groups correlation matrix was calculated for the two populations, sexes combined, by WITHIN, a modification of a multiple group discriminant function program written by Davies (1971). The principal components of this matrix were extracted using the PA1 option of the SPSS FACTOR procedure (Nie, et al. 1975) and those components with eigenvalues greater than 1.0 were rotated via the VARIMAX criterion.

The original measurements were converted into standardized Z-scores and multiplied by the component score coefficient matrix output from the SPSS FACTOR procedure. This yields a set of principal component scores for each individual.

Mean principal component scores were calculated for each group, sexes separate, and tested for homogeneity by a two-way Multivariate Analysis of Variance (MANOVA) from the General Linear Models (GLM) procedure of SAS76 (Barr, et al. 1976) (for an excellent discussion of MANOVA, refer to Cooley and Lohnes (1971) or Tatsuoka (1971)).

Both group and sex effects were analyzed and the F-values from these analyses were used as measures of group differences.

IV. RESULTS

Principal Components Analysis

Although more than 10 components were extracted from each of the groups in the following analysis, only the first 10 components were rotated. This was done because in at least two groups only the first 10 components were biologically interpretable, the remaining components probably resulting from residual "noise." The number of rotated components was thus limited to 10 for all groups to facilitate group comparisons. A minimal amount of information was lost because of this procedure.

In all subsequent analyses, the more important variable loadings for each component are extracted from the component matrix and listed after the biological interpretation of the component.

Murray River males. Initially, 12 components with eigenvalues greater than 1.0 were extracted from the Murray River males raw data matrix. However, only 10 of these components were rotated (refer to Table 8). This was done to facilitate later component structure comparisons. Together, these 10 rotated components account for 81.2% of the total variation among the variables.

I. Facial forwardness. This component, accounting for 15.1% of the total variation, expresses the forward extension of the face relative to the auricular region. The highest loadings are on the radii measured from the external auditory meatus and on basion-nasion length (BNL) and basion-prosthion length (BPL). There is also a

TABLE 3. MURRAY RIVER AUSTRALIAN MALES VARIMAX ROTATED PRINCIPAL COMPONENT MATRIX.

	VARIABLE	CODE NAME	I	II	III	IV	V	VI	VII	VIII	IX	X	COMMUNALITY
1	GLAB-OCC L	GOL	0.586	0.392	0.110	0.225	-0.240	0.281	0.010	0.137	0.165	0.270	0.815
2	BAS-NAS L	BNL	0.823	0.179	0.148	-0.214	0.069	-0.171	-0.086	0.037	0.201	0.042	0.862
3	BAS-BREG HT	BBH	0.059	0.265	0.118	0.190	0.213	0.155	0.026	-0.804	-0.003	0.267	0.911
4	MAX BR	XCB	-0.092	0.806	-0.079	-0.023	-0.048	0.184	-0.104	-0.243	-0.161	0.140	0.817
5	MAX FRONT BR	XFB	-0.025	0.645	-0.093	0.075	-0.253	0.207	-0.066	-0.299	0.098	0.290	0.726
6	BISTEPHANIC	STB	-0.119	0.310	-0.031	0.057	-0.385	0.163	-0.001	-0.460	0.243	0.311	0.656
7	BIZYG BR	ZYB	0.382	0.620	-0.315	-0.100	-0.049	0.186	-0.168	-0.036	-0.222	-0.128	0.772
8	BIAURIC BR	AUB	0.164	0.668	-0.221	-0.108	0.018	0.234	-0.219	-0.069	-0.265	-0.199	0.785
9	BAS-PROSTH	BPL	0.575	0.190	0.118	-0.116	-0.695	-0.085	-0.073	0.168	0.107	0.007	0.929
10	NAS-PROSTH	NPH	0.195	0.115	0.227	0.021	-0.230	-0.249	-0.824	0.096	0.039	0.090	0.916
11	NASAL HT	NLH	0.384	0.191	0.091	-0.082	0.177	-0.067	-0.726	0.197	-0.038	0.042	0.804
12	ORBIT HT	OBH	0.168	0.679	0.110	0.029	-0.021	0.131	-0.406	0.467	0.012	-0.149	0.473
13	ORBIT BR	OBB	0.177	0.641	0.069	0.166	-0.005	-0.429	-0.042	0.150	0.200	0.064	0.727
14	NASAL BR	NLB	0.361	0.576	-0.045	-0.149	0.005	-0.048	-0.040	0.274	0.040	0.321	0.670
15	PALATE BR	MAB	0.293	0.356	-0.066	-0.026	-0.009	0.150	-0.575	-0.035	-0.166	0.055	0.609
16	MASTOID L	MDH	-0.001	0.612	-0.073	0.140	-0.151	-0.196	-0.3[illegible]7	-0.168	-0.102	0.222	0.648
17	BIMAXILLARY	ZMB	0.357	0.219	-0.400	0.183	-0.091	0.387	-0.363	0.044	0.180	-0.058	0.696
18	ZYGOMAX SUB	SSS	0.249	-0.037	0.788	0.050	-0.123	0.078	-0.263	-0.102	0.219	-0.095	0.845
19	BIFRONTAL	FMB	0.423	0.698	-0.083	0.238	-0.060	-0.004	0.048	0.081	0.372	0.019	0.881
20	NAS-FR SUBT	NAS	0.274	-0.082	0.087	0.130	-0.050	-0.410	0.063	0.153	0.738	-0.142	0.869
21	BIORBITAL	EKB	0.380	0.808	-0.215	0.067	0.011	-0.047	-0.061	0.079	0.277	-0.016	0.937
22	INTERORB	DKB	0.499	0.275	-0.473	-0.089	-0.039	0.307	-0.144	0.105	0.356	-0.052	0.814
23	NAS-DAC SUB	NDS	0.206	-0.154	0.647	0.201	0.115	0.151	-0.152	0.219	-0.244	0.166	0.719
24	CHEEK HT	WMH	0.183	0.134	-0.112	0.042	-0.278	-0.127	-0.481	-0.288	0.147	0.490	0.735
25	SUPRAORB PR	SOS	0.051	0.248	-0.210	-0.068	0.105	0.166	-0.042	-0.212	0.704	-0.024	0.695
26	GLABELLA PR	GLS	-0.065	0.012	0.129	-0.041	0.049	-0.320	0.065	0.200	-0.146	0.488	0.431
27	NAS-BREG C	FRC	-0.040	0.407	0.088	0.029	0.019	0.483	0.001	-0.173	-0.013	0.679	0.901
28	NAS-BREG SUB	FRS	-0.085	0.166	-0.007	0.017	-0.042	0.898	0.123	-0.015	-0.099	0.177	0.884
29	NAS FRACTION	FRF	-0.023	0.120	-0.012	0.020	0.134	0.099	-0.207	-0.298	-0.161	0.788	0.822
30	BREG-LAM C	PAC	0.390	0.058	0.028	0.729	-0.151	0.173	-0.113	-0.215	0.174	0.061	0.834
31	BREG-LAM SUB	PAS	-0.057	0.077	0.084	0.931	0.021	-0.043	-0.027	-0.140	-0.050	-0.008	0.906
32	BREG FRACT	PAF	0.298	-0.025	0.002	0.630	-0.288	0.176	-0.385	-0.035	0.223	0.037	0.666
33	NASION RAD	NAR	0.882	0.087	0.082	0.039	0.109	-0.028	-0.048	0.175	0.203	-0.055	0.883
34	SUBSPIN RAD	SSR	0.852	0.094	0.322	0.084	-0.141	-0.002	-0.177	-0.086	0.071	-0.072	0.915
35	PROSTH RAD	PRR	0.668	0.232	0.220	0.088	-0.517	-0.145	-0.286	-0.049	0.106	-0.031	0.941
36	ZYGOORB RAD	ZOR	0.904	0.103	-0.089	0.022	0.009	-0.145	-0.122	0.007	0.002	-0.067	0.876
37	ZYGOMAX RAD	ZMR	0.869	0.088	-0.206	0.090	-0.081	-0.054	-0.012	-0.036	-0.173	-0.016	0.844
38	NAS ANG B-P	NAA	0.028	0.082	-0.056	0.030	-0.876	0.180	0.332	0.146	-0.059	-0.073	0.952
39	PROSTH ANG	PRA	0.130	-0.072	-0.065	-0.086	0.898	-0.025	0.283	-0.151	0.077	0.026	0.950
40	BAS ANG N-P	BAA	-0.213	-0.009	0.188	0.159	0.041	-0.168	-0.864	-0.020	-0.043	0.038	0.892
41	NAS ANG B-B	NBA	-0.219	0.029	0.028	0.278	0.218	0.008	0.066	-0.839	-0.076	-0.042	0.890
42	BAS ANG N-B	BBA	-0.342	0.129	-0.066	-0.096	-0.193	0.387	0.011	0.577	-0.050	0.494	0.914
43	ZYGOMAX ANG	SSA	-0.087	0.120	-0.911	0.042	0.096	0.089	0.115	0.123	-0.135	0.063	0.921
44	NAS-FR ANG	NFA	-0.171	0.260	-0.109	-0.061	0.042	0.451	-0.070	-0.146	-0.702	0.159	0.862
45	NAS-DAC ANG	NDA	0.187	0.276	-0.754	-0.198	-0.102	0.101	0.022	-0.091	0.398	-0.151	0.929
46	FRONTAL ANG	FRA	0.083	0.040	0.030	-0.027	0.065	-0.874	-0.181	-0.052	0.084	0.103	0.831
47	PARIETAL ANG	PAA	0.283	-0.054	-0.120	-0.799	-0.106	0.136	-0.038	0.047	0.178	0.061	0.798
	EIGENVALUE		7.100	5.465	3.570	3.045	3.173	3.627	3.606	3.100	2.875	2.595	
	PERCENT OF TRACE		15.105	11.628	7.595	6.478	6.751	7.717	7.672	6.595	6.116	5.520	

moderate loading on glabello-occipital length (GOL). The pattern of loadings indicates that this component measures the preauricular extension of the skull only and not overall cranial length. The bifrontal breadth (FMB) and interorbital breadth (DKB) loadings probably reflect the overall size-related nature of this component.

GOL	.586	PRR	.668
BNL	.823	ZOR	.904
BPL	.575	ZMR	.869
NAR	.882	FMB	.423
SSR	.852	DKB	.499

II. Cranial breadth. This component, which accounts for 11.6% of the total variation, expresses general vault and facial breadth. The relatively high loading of mastoid height (MDH) on this component is rather interesting. The frontal chord (FRC) also loads on this component, although the loading is rather small.

XCB	.806	NLB	.576
XFB	.645	MDH	.612
ZYB	.620	FMB	.698
AUB	.688	EKB	.808
OBB	.641	FRC	.407

III. Midfacial prominence. Accounting for 7.6% of the total variation, this component expresses the prominence of the midfacial region. Subspinale angle (SSA) measures facial flatness (or prominence) at subspinale relative to the bimaxillary chord (ZMB). The higher the angle, the flatter the maxillary region is in this regard (Howells 1973:

185). The angle is calculated from the bimaxillary chord (ZMB) and the subtense of subspinale to that chord (SSS). Naso-dacryal angle (NDA) measures the relative positions of the roof of the nose and the plane of the eyes (Howells 1973: 186). It is calculated from the interorbital breadth (DKB) and the subtense of the deepest point in the profile of the the nasal bones to the interorbital breadth (NDS).

SSS	.788	DKB	-.473
NDS	.647	NDA	-.754
SSA	-.911	ZMB	-.400

IV. Parietal size and profile. This component, accounting for 6.5% of the total variation, simply and consistently deals with the parietal. It expresses both the overall sagittal length of the parietal as well as the flatness (or peakedness) of its sagittal profile as measured by the parietal angle (PAA) (refer to Figure 3, p. 18).

PAC	.729	PAF	.630
PAS	.931	PAA	-.795

V. Prognathism. This component measures prognathism (the relative projection of the alveolar region). It accounts for 6.8% of the total variation. Prognathism is measured at prosthion both by basion-prosthion length (BPL) and by prosthion radius (PRR) as well as two of the angles of the facial triangle: nasion angle (NAA) and prosthion angle (PRA). These angles are illustrated in Figure 1 (p. 16).

BPL	-.695	NAA	-.876
PRR	-.517	PRA	.898

VI. Frontal flatness. This component, which accounts for 7.7% of the total variation, expresses the relative flatness of the frontal

bone, both in the sagittal and transverse planes. The pattern of loadings indicates that this component measures the shape of the frontal as opposed to the length of the frontal. The highest loadings are on frontal angle (FRA) and frontal subtense (FRS). The frontal angle measures the flatness of the frontal in the sagittal profile. The higher the angle, the flatter the frontal bone is in this respect (refer to Figure 3, p. 18). The nasio-frontal angle (NFA) measures the transverse flatness of the supraorbital region. It is calculated from bifrontal breadth (FMB) and the subtense of nasion to that breadth (NAS). The orbital breadth (OBB) loading on this component is probably related to the transverse breadth of the frontal.

OBB	-.429	FRA	-.874
NAS	-.410	FRS	.898
FRC	.483	NFA	.451

VII. Facial height. This is a well defined component, expressing the vertical height of the face and accounting for 7.7% of the total variation. The highest loadings are for nasion-prosthion height (NPH) and basion angle (BAA) indicating this component is most likely related to vertical maxillary growth (see Howells 1973: 132). Basion angle is one of the angles of the facial triangle (refer to Figure 1, p. 16). The other loadings are measures of facial height (e.g., cheek height—WMH) with the exception of external palatal breadth (MAB). The presence of this variable on this component is rather puzzling.

NPH	-.824	MAB	-.575
NLH	-.726	WMH	-.481
OBH	-.406	BAA	-.864

VIII. Vault Height. Relatively distinct from the previous component of facial height, this component measures the height of the cranial vault. It accounts for 6.6% of the total variation. The highest loadings are on basion-bregma height (BBH) and two angles measuring vault height (refer to Figure 2, p. 17): nasion-bregma angle (NBA) and basion-bregma angle (BBA). The loading of orbital height (OBH) on this component probably expresses some residual facial height not accounted for by the previous component. The loading of bistephanic breadth (STB) on this component is puzzling.

BBH	-.804	NBA	-.839
STB	-.460	BBA	.577
OBH	.467		

IX. Interorbital prominence. This is a relatively specific component, expressing the prominence of the interorbital region. It accounts for 6.1% of the total variation. The principal loadings are on nasio-frontal subtense (NAS) (which also loaded on the frontal flatness component) and supraorbital subtense (SOS), the projection of the supraorbital region relative to the frontal squama. The naso-dacryal angle (NDA), the angle that measures the relative positions of the roof of the nose and the plane of the eyes, also has a moderate loading on this component. However, it has a higher loading on the midfacial prominence component.

NAS	.738	NDA	.398
SOS	.704		

X. Frontal length. This component is fairly distinct from Component IV which measures frontal flatness. This component measures

frontal bone length, independent of shape. It accounts for 5.5% of the total variation. The highest loadings are on the frontal chord (FRC) and the fraction of the chord where the highest curve of the frontal occurs (FRF). There is also a moderate loading on basion-bregma angle (BBA), the angle subtended by the frontal chord (refer to Figure 2, p. 17). The moderate loading of glabella projection (GLS) on this component is interesting, but the presence of cheek height (WMH) is somewhat puzzling.

WMH	.490	FRF	.788
GLS	.488	BBA	.494
FRC	.679		

Murray River females. Twelve components were initially extracted from the data matrix with eigenvalues greater than 1.0, however only 10 of these components were rotated (refer to Table 9). This was done to facilitate later group comparisons. Together, these 10 components account for 79.9% of the total variation.

I. Facial forwardness. This component, which accounts for 10.8% of the total variation, is nearly identical to Component I of the males. It measures the forward extension of the face relative to the auricular region.

GOL	.627	SSR	.774
BNL	.732	PRR	.625
BBH	.442	ZOR	.797
NAR	.857	ZMR	.732
BPL	.430		

TABLE 9. MURRAY RIVER AUSTRALIAN FEMALES VARIMAX ROTATED PRINCIPAL COMPONENT MATRIX.

	VARIABLE	CODE NAME	I	II	III	IV	V	VI	VII	VIII	IX	X	COMMUNALITY
1	GLAB-OCC L	GOL	0.627	0.009	-0.123	0.019	-0.081	0.254	0.263	-0.230	0.499	-0.015	0.851
2	BAS-NAS L	BNL	0.732	-0.048	-0.260	0.047	-0.225	-0.031	-0.059	-0.198	0.377	-0.035	0.846
3	BAS-BREG HT	BBH	0.442	0.017	-0.095	0.077	-0.106	0.054	-0.360	-0.073	0.700	0.117	0.864
4	MAX BR	XCB	0.139	0.269	-0.058	-0.077	0.019	0.120	0.013	-0.152	0.776	-0.112	0.754
5	MAX FRONT BR	XFB	-0.033	0.380	0.079	-0.377	0.058	0.213	-0.018	-0.203	0.657	-0.169	0.843
6	BISTEPHANIC	STB	-0.124	0.255	-0.064	-0.458	-0.194	0.196	-0.054	-0.112	0.557	-0.151	0.721
7	BIZYG BR	ZYB	0.158	-0.040	-0.053	0.195	0.018	-0.043	0.039	-0.663	0.545	0.018	0.807
8	BIAURIC BR	AUB	0.123	0.107	-0.138	0.058	0.108	0.001	-0.136	-0.361	0.762	0.011	0.791
9	BAS-PROSTH	BPL	0.430	-0.008	0.724	0.011	-0.146	-0.008	0.109	-0.158	0.030	-0.106	0.779
10	NAS-PROSTH	NPH	0.156	0.860	0.078	-0.071	-0.150	-0.116	0.140	-0.116	0.211	0.149	0.911
11	NASAL HT	NLH	-0.068	0.695	-0.058	0.078	-0.328	-0.134	0.017	0.062	0.359	-0.020	0.761
12	ORBIT HT	OBH	-0.065	0.140	-0.259	0.306	-0.501	-0.254	-0.010	0.152	0.293	-0.205	0.654
13	ORBIT BR	OBB	0.122	0.180	0.119	0.112	-0.144	0.077	-0.190	-0.776	-0.061	-0.024	0.743
14	NASAL BR	NLB	0.021	-0.157	0.638	0.123	-0.148	-0.013	0.061	-0.149	0.115	-0.107	0.521
15	PALATE BR	MAB	0.075	0.245	0.452	0.067	0.173	-0.241	-0.039	-0.250	0.403	0.095	0.598
16	MASTOID L	MDH	0.005	0.317	0.375	0.352	0.163	0.352	0.343	0.030	0.258	0.115	0.714
17	BIMAXILLARY	ZMB	0.161	-0.169	0.088	0.091	0.099	0.174	0.132	-0.742	0.232	0.098	0.742
18	ZYGOMAX SUB	SSS	-0.006	-0.060	0.320	-0.333	-0.544	-0.215	0.010	-0.046	0.081	0.566	0.658
19	BIFRONTAL	FMB	0.120	0.186	0.051	-0.012	-0.156	-0.014	-0.092	-0.827	0.212	-0.242	0.872
20	NAS-FR SUBT	NAS	0.080	0.129	0.098	0.081	-0.870	0.093	0.050	-0.248	0.027	0.017	0.870
21	BIORBITAL	EKB	0.119	0.190	0.100	0.128	-0.019	0.042	-0.007	-0.865	0.159	-0.301	0.943
22	INTERORB	DKB	0.315	-0.038	0.041	0.016	-0.081	0.061	0.163	-0.343	0.200	-0.512	0.559
23	NAS-DAC SUB	NDS	0.029	0.308	-0.297	0.178	-0.121	0.023	0.164	-0.018	0.005	0.512	0.520
24	CHEEK HT	WMH	0.163	0.543	0.109	0.198	0.238	0.258	0.070	-0.296	0.016	-0.064	0.593
25	SUPRAORB PR	SOS	0.312	-0.039	0.164	-0.318	-0.076	0.130	0.047	-0.521	0.001	0.220	0.572
26	GLABELLA PR	GLS	0.257	-0.369	0.047	0.059	0.258	0.198	0.323	-0.419	-0.044	-0.129	0.612
27	NAS-BREG C	FRC	0.360	0.118	0.031	-0.872	-0.139	-0.074	0.459	-0.035	0.664	0.176	0.959
28	NAS-BREG SUB	FRS	0.157	0.008	-0.023	-0.791	0.047	-0.080	0.313	0.174	0.265	0.014	0.859
29	NAS FRACTION	FRF	0.138	0.016	0.072	0.213	-0.138	-0.036	0.493	-0.018	0.596	-0.141	0.708
30	BREG-LAM C	PAC	0.156	-0.028	-0.042	0.267	-0.058	0.713	-0.013	-0.053	0.499	-0.096	0.871
31	BREG-LAM SUB	PAS	0.043	-0.041	-0.047	0.008	-0.019	0.939	-0.116	-0.036	0.034	-0.169	0.959
32	BREG FRACT	PAF	0.166	-0.114	0.024	0.066	-0.040	0.752	-0.049	-0.039	0.184	0.234	0.705
33	NASION RAD	NAR	0.857	0.073	-0.192	-0.072	-0.114	0.106	0.069	-0.207	0.264	-0.052	0.926
34	SUBSPIN RAD	SSR	0.774	0.043	0.466	-0.079	-0.154	-0.056	-0.049	-0.124	0.100	0.131	0.896
35	PROSTH RAD	PRR	0.625	0.195	0.657	-0.073	-0.096	-0.059	0.012	-0.175	0.022	0.052	0.913
36	ZYGORB RAD	ZOR	0.797	0.057	0.143	-0.057	0.291	0.034	-0.085	-0.267	0.021	-0.210	0.871
37	ZYG MAX RAD	ZMR	0.732	0.053	0.124	0.153	0.384	0.143	-0.117	-0.039	-0.042	-0.334	0.875
38	NAS ANG B-P	NAA	-0.107	-0.295	0.837	-0.003	0.042	0.051	0.081	0.023	-0.299	-0.167	0.928
39	PROSTH ANG	PRA	0.220	-0.280	-0.854	0.052	-0.011	0.004	-0.164	0.017	0.244	0.030	0.952
40	BAS ANG N-P	BAA	-0.124	0.890	-0.121	-0.087	-0.031	-0.119	0.041	-0.024	0.132	0.190	0.900
41	NAS ANG B-B	NBA	-0.064	-0.057	-0.095	0.163	0.085	0.152	-0.855	0.010	0.225	0.065	0.853
42	BAS ANG N-B	BBA	-0.147	0.124	0.181	-0.138	-0.046	-0.133	0.861	0.043	0.098	0.135	0.880
43	ZYGOMAX ANG	SSA	0.085	-0.027	-0.257	0.366	0.555	0.295	0.035	-0.281	0.026	-0.493	0.927
44	NAS-FR ANG	NFA	-0.052	-0.077	-0.084	-0.093	0.876	-0.092	-0.085	-0.017	0.043	-0.113	0.822
45	NAS-DAC ANG	NDA	0.174	-0.290	0.281	-0.146	0.053	0.025	-0.051	-0.172	0.097	-0.766	0.846
46	FRONTAL ANG	FRA	0.001	0.054	0.029	0.888	-0.131	0.032	-0.017	-0.231	0.145	0.047	0.885
47	PARIETAL ANG	PAA	0.072	0.008	0.034	0.194	-0.039	-0.797	0.174	0.082	0.291	0.163	0.829
	EIGENVALUE		5.062	3.563	4.125	2.831	3.293	3.465	2.755	4.572	5.361	2.543	
	PERCENT OF TRACE		10.769	7.581	8.777	6.024	7.007	7.372	5.861	9.728	11.406	5.411	

II. Facial height. Nearly identical to Component VII of the males, this component accounts for 7.6% of the total variation. It measures the vertical height of the face. The highest loading is on the basion angle (BAA) of the facial triangle (refer to Figure 1, p. 16). The low frontal breadth (XFB) loading on this component is puzzling.

NPH	.860	WMH	.543
NLH	.699	BAA	.890
XFB	.380		

III. Prognathism. This component accounts for 8.8% of the total variation. It conforms fairly well with Component V of the males with the exception of the nasal breadth (NLB), palatal breadth (MAB) and mastoid height (MDH) loadings. The other loadings present a clear picture of alveolar prognathism (refer to Figure 1, p. 16).

BPL	.724	SSR	.466
NLB	.638	PRR	.657
MAB	.452	NAA	.837
MDH	.375	PRA	-.854

IV. Frontal profile flatness. This is a somewhat nebulous component accounting for 6.0% of the total variation. The high loadings on the frontal subtense (FRS) and the frontal angle (FRA) quite clearly measure the flatness (or peakedness) of the frontal in the sagittal profile (refer to Figure 3, p. 18). This component is fairly similar to Component VI of the males in this regard. The maximum frontal breadth (XFB) and bistephanic breadth (STB) loadings express the width of the frontal in a transverse profile. Whereas the

male Component VI also measured the flatness of the subraorbital region in the transverse profile via the nasio-frontal angle (NFA), this component does not.

XFB	-.377	FRS	-.791
STB	-.458	FRA	.886

V. Full facial flatness. This component measures the flatness of the plane of the face, both in the orbital region via the nasio-frontal angle (NFA) and in the maxillary region via the subspinale angle (SSA). It accounts for 7.0% of the total variation.

OBH	-.501	ZMR	.384
SSS	-.544	SSA	.555
NAS	-.870	NFA	.876

VI. Parietal size and profile. This component is identical to Component IV of the males. It measures the size and flatness of the parietal in the sagittal profile (refer to Figure 3, p. 18). It accounts for 7.4% of the total variation.

PAC	.713	PAF	.752
PAS	.939	PAA	-.797

VII. Frontal length. This component accounts for 5.9% of the total variation. It is very similar to Component X of the males in measuring frontal length in the sagittal profile, but it also appears to measure vault height somewhat via the nasion-bregma angle (NBA) (refer to Figure 2, p. 17).

FRC	.459	NBA	-.855
FRF	.493	BBA	.861

VIII. Facial breadth. Whereas the male Component II measured general cranial breadth—both breadth of the face and of the vault—this component measures only facial breadth. It accounts for 9.7% of the total variation. The pattern of loadings is quite distinct, with the highest loadings for the upper facial breadths and slightly lower loadings for bimaxillary breadth (ZMB) and bizygomatic breadth (ZYB). Supraorbital subtense (SOS) and glabella projection (GLS) also have moderate loadings on this component.

ZYB	-.663	EKB	-.865	FMB	-.827
OBB	-.776	SOS	-.521		
ZMB	-.742	GLS	-.419		

IX. Cranial size. This component accounts for 11.4% of the total variation. This is a general, size-related component, expressing cranial length, breadth, and height. It is a sort of "catch all" component, probably resulting from rotating only 10 of the 12 components with eigenvalues greater than 1.0. If all 12 components had been rotated, this component would probably not exist in its present form. The "catch all" nature of this component is further confirmed by the high percentage of the total variation accounted for by it.

GOL	.499	XFB	.657	MAB	.403
BNL	.377	STB	.557	FRC	.664
BBH	.700	ZYB	.545	FRF	.596
XCB	.776	AUB	.762	PAC	.499

X. Midfacial prominence. In contrast to Component V, which measures the flatness (or prominence) of the face as a whole, this

component expresses the relative prominence of the midfacial region—especially the nasal saddle—to the plane of the face. It is quite similar to the male Component III in this regard. It accounts for 5.4% of the total variation.

SSS	.566	SSA	-.493
DKB	-.512	NDA	-.766
NDS	.512		

Larson Site Arikara males. Only 10 of the original 13 components with eigenvalues greater than 1.0 were rotated (refer to Table 10). This was done to facilitate group comparisons. Together, the 10 rotated components account for 77.3% of the total variation.

I. Facial size and projection. This is largely a size related component accounting for 13.4% of the total variation. It is somewhat of a "catch all" component, probably brought on by rotating only 10 of the 13 components with eigenvalues greater than 1.0. However, it is primarily related to facial size and projection. It is somewhat similar to the Murray River male Component I and female Component I in measuring facial forwardness, but it also measures supraorbital flatness via the nasio-frontal angle (NFA). It also has high loadings on some of the upper facial breadth variables. Supraorbital subtense (SOS) also has a relatively high loading on this component.

GOL	.762	NAS	.875	NAR	.713
BNL	.585	EKB	.598	SSR	.449
OBB	.602	SOS	.651	PRR	.425
FMB	.578	PAC	.478	ZOR	.446
NFA	-.827				

TABLE 10. LARSON SITE ARIKARA MALES VARIMAX ROTATED PRINCIPAL COMPONENT MATRIX.

VARIABLE	CODE NAME	I	II	III	IV	V	VI	VII	VIII	IX	X	COMMUNALITY
1 GLAB-OCC L	GOL	0.762	0.066	0.047	-0.290	0.153	-0.020	0.131	0.184	0.060	-0.088	0.757
2 BAS-NAS L	BNL	0.585	0.160	-0.314	-0.265	0.328	0.160	0.142	0.420	-0.101	-0.064	0.881
3 BAS-BREG HT	BBH	0.176	-0.090	-0.232	-0.266	0.625	-0.249	0.312	-0.171	0.063	0.073	0.753
4 MAX BR	XCB	-0.127	0.710	0.108	-0.038	-0.314	0.026	-0.185	-0.099	0.028	-0.167	0.705
5 MAX FRONT BR	XFB	0.013	0.756	-0.004	0.001	-0.135	-0.085	0.129	-0.104	0.246	0.004	0.685
6 BISTEPHANIC	STB	0.148	0.444	-0.199	-0.097	-0.276	-0.116	-0.005	-0.025	0.328	0.031	0.452
7 BIZYG BR	ZYB	0.191	0.835	-0.010	-0.008	0.106	-0.060	0.085	-0.025	-0.048	-0.123	0.774
8 BIAURIC BR	AUB	-0.074	0.811	-0.167	-0.014	-0.027	-0.065	0.110	-0.148	-0.111	-0.163	0.769
9 BAS-PROSTH	BPL	0.226	-0.007	-0.108	-0.135	0.022	0.082	0.139	0.882	-0.149	0.105	0.918
10 NAS-PROSTH	NPH	0.199	-0.037	0.916	0.025	0.088	0.105	0.024	0.109	-0.076	0.031	0.919
11 NASAL HT	NLH	-0.004	0.018	0.849	-0.020	-0.144	0.019	0.029	-0.111	-0.084	0.111	0.774
12 ORBIT HT	OBH	0.147	0.250	0.427	-0.261	0.048	-0.124	-0.402	-0.256	-0.240	0.165	0.664
13 ORBIT BR	OBB	0.602	0.265	0.271	0.079	0.102	-0.006	-0.224	0.192	0.215	0.005	0.659
14 NASAL BR	NLB	0.169	-0.150	-0.190	0.246	-0.191	0.078	0.011	0.433	-0.179	-0.264	0.480
15 PALATE BR	MAB	0.127	0.062	-0.017	-0.185	-0.023	0.443	0.288	-0.050	0.009	0.308	0.432
16 MASTOID L	MDH	0.144	0.200	0.385	0.009	0.206	0.252	0.223	-0.038	0.291	-0.061	0.454
17 BIMAXILLARY	ZMB	-0.146	0.198	0.001	0.226	0.286	0.282	0.540	0.286	0.113	0.095	0.668
18 ZYGOMAX SUB	SSS	0.228	-0.276	0.208	0.120	0.101	0.046	-0.089	0.182	-0.009	0.795	0.871
19 BIFRONTAL	FMB	0.578	0.585	0.158	0.251	0.069	0.032	-0.059	0.205	-0.135	0.084	0.862
20 NAS-FR SUBT	NAS	0.875	0.013	-0.026	0.093	-0.179	0.023	0.023	0.079	0.027	0.296	0.903
21 BIORBITAL	EKB	0.595	0.606	0.151	0.260	0.108	0.096	-0.011	0.223	-0.081	0.089	0.901
22 INTERORB	DKB	0.326	0.315	-0.127	0.514	0.020	0.078	0.142	0.239	-0.137	0.140	0.603
23 NAS-DAC SUB	NDS	0.164	0.199	-0.175	-0.750	0.077	0.161	0.012	0.254	-0.141	0.059	0.779
24 CHEEK HT	WMH	-0.086	-0.026	0.124	0.089	0.019	0.067	0.772	0.147	-0.111	-0.157	0.687
25 SUPRAORB PR	SOS	0.651	-0.069	-0.191	0.047	-0.080	-0.281	0.051	0.184	-0.267	-0.120	0.678
26 GLABELLA PR	GLS	0.217	0.145	-0.064	0.094	0.016	-0.048	0.685	-0.127	-0.227	-0.253	0.684
27 NAS-BREG C	FRC	0.213	0.087	-0.136	-0.190	-0.507	-0.097	0.512	-0.064	0.347	0.017	0.762
28 NAS-BREG SUB	FRS	0.104	0.030	-0.124	0.008	-0.281	-0.106	0.025	-0.137	0.860	0.010	0.876
29 NAS FRACTION	FRF	0.117	-0.067	-0.102	-0.204	-0.370	-0.150	0.713	0.053	-0.074	0.144	0.767
30 BREG-LAM C	PAC	0.478	0.002	0.015	-0.096	0.165	-0.591	0.081	-0.040	0.060	0.051	0.629
31 BREG-LAM SUB	PAS	0.045	0.099	-0.077	0.100	0.093	-0.930	-0.009	0.005	0.033	0.018	0.903
32 BREG FRACT	PAF	0.237	0.081	0.087	-0.342	-0.035	-0.635	0.091	-0.013	0.403	0.057	0.766
33 NASION RAD	NAR	0.713	0.157	0.031	-0.052	-0.144	-0.084	0.019	0.393	0.184	0.010	0.746
34 SUBSPIN RAD	SSR	0.449	-0.103	0.086	-0.009	0.101	0.007	-0.002	0.745	-0.071	0.226	0.840
35 PROSTH RAD	PRR	0.425	-0.150	0.165	0.019	0.093	0.004	0.006	0.784	-0.032	0.255	0.934
36 ZYGORB RAD	ZOR	0.446	-0.026	-0.058	0.015	-0.041	0.024	0.079	0.664	0.172	-0.270	0.756
37 ZYGOMAX RAD	ZMR	0.319	-0.040	-0.011	-0.231	-0.116	-0.099	0.076	0.730	-0.089	-0.450	0.886
38 NAS ANG B-P	NAA	-0.270	-0.115	-0.249	0.019	-0.266	-0.072	0.041	0.768	-0.081	0.194	0.860
39 PROSTH ANG	PRA	0.298	0.183	-0.649	-0.173	0.301	0.038	0.029	-0.424	0.064	-0.186	0.896
40 BAS ANG N-P	BAA	-0.080	-0.094	0.909	0.133	-0.022	0.026	-0.089	-0.302	0.015	0.035	0.960
41 NAS ANG B-B	NBA	-0.220	-0.221	0.023	-0.040	0.739	-0.285	-0.026	-0.340	-0.062	0.088	0.855
42 BAS ANG N-B	BBA	-0.039	0.119	0.105	0.041	-0.890	0.061	0.195	-0.049	0.270	-0.021	0.937
43 ZYGOMAX ANG	SSA	-0.262	0.348	-0.182	-0.013	0.029	0.073	0.304	-0.062	0.047	-0.708	0.830
44 NAS-FR ANG	NFA	-0.827	0.155	0.078	-0.025	0.220	-0.025	-0.051	-0.035	-0.083	-0.327	0.861
45 NAS-DAC ANG	NDA	0.084	0.059	0.070	0.927	-0.039	-0.080	0.083	-0.039	0.019	0.064	0.895
46 FRONTAL ANG	FRA	-0.009	0.006	0.079	-0.103	0.038	0.068	0.305	0.129	-0.846	0.024	0.848
47 PARIETAL ANG	PAA	0.221	-0.119	0.097	-0.188	-0.047	0.819	0.068	-0.013	0.002	0.011	0.785
EIGENVALUE		6.289	4.245	3.503	2.724	3.121	3.076	3.008	5.071	2.590	2.291	
PERCENT OF TRACE		13.381	9.033	8.305	5.796	6.641	6.546	6.399	10.789	5.511	4.875	

II. Cranial breadth. This component is very similar to the Murray River males Component II. It expresses general cranial breadth, both of the vault and of the face. It accounts for 9.0% of the total variation.

XCB	.710	AUB	.811	ZYB	.835
XFB	.756	FMB	.585		
STB	.444	EKB	.606		

III. Facial height. This is a simple and precise component expressing facial height. It accounts for 8.3% of the total variation. It is very similar to the Murray River males Component VII and females Component II with the exception of the moderate loading of mastoid height (MDH) on this component.

NPH	.916	MDH	.385
NLH	.849	PRA	-.649
OBH	.427	BAA	.909

IV. Interorbital prominence. This component accounts for 5.8% of the total variation. It quite clearly expresses the prominence of the interorbital region. The naso-dacryal angle (NDA) measures the relative position of the roof the nose to the plane of the eyes. The higher the angle, the less prominent the nasal saddle is in this regard. It is calculated from interorbital breadth (DKB) and the subtense of the nasal saddle to that breadth (NDS).

DKB	.514	NDA	.927
NDS	-.750		

V. Vault height. This is another uncomplicated component. It clearly measures the height of the cranial vault and accounts

for 6.6% of the total variation (refer to Figure 2, p. 17).

BBH	.625	NBA	.739
FRC	-.507	BBA	-.890

VI. Parietal size and profile. The parietal appears to be a very cohesive structure within the cranium. All four groups isolate the parietal on a specific component. This component accounts for 6.5% of the total variation. The loading of palatal breadth on a parietal component is puzzling.

PAC	-.591	PAF	-.635
PAS	-.930	PAA	.819
MAB	.443		

VII. Frontal length. This is a poorly defined component, accounting for 6.4% of the total variation. It appears to be primarily related to frontal length, but its highest loading is on cheek height (WMH). Glabella projection (GLS) also has a high loading on this component.

OBH	-.402	GLS	.685
ZMB	.540	FRC	.512
WMH	.772	FRF	.713

VIII. Prognathism. This component accounts for 10.8% of the total variation. It primarily expresses the prognathism of the alveolar region although it also measures the forward extension of the face relative to the auricular region ("facial forwardness").

BNL	.420	PRR	.784
BPL	.882	ZOR	.664

NLB	.433	ZMR	.700
NAR	.393	NAA	.768
SSR	.745	PRA	-.424

IX. Frontal profile flatness. This is a relatively specific component, measuring the flatness or prominence of the frontal in the sagittal profile (refer to Figure 3, p. 18). It accounts for 5.5% of the total variation. The loading of parietal subtense fraction (PAF) on this component is rather puzzling. It may indicate that this component is somewhat related to the sagittal curve of the skull in general, although it appears to be restricted to the frontal area.

FRS	.860	FRA	-.846
PAF	.403		

X. Subnasal flatness. This component measures facial flatness or prominence at subspinale. It accounts for 4.9% of the total variation. The highest loadings are on the subtense of subspinale to the bimaxillary chord (ZMB) and the subspinale angle (SSA). The higher the angle, the flatter the maxillary region is in relation to the bimaxillary diameter. The zygomaxillary radius (ZMR) measures the length between zygomaxillare and the external auditory meatus.

SSS	.795	SSA	-.708
ZMR	-.450		

Larson Site Arikara females. Initially, 13 components with eigenvalues greater than 1.0 were extracted from the data matrix; however, only 10 of these components were rotated to facilitate later

component structure comparisons between groups. Together, these 10 components account for 76.6% of the total variation (refer to Table 11).

I. Facial size and projection. This component is very similar to Component I of the Arikara males. It is somewhat of a "catch all" component, accounting for 16.6% of the total variation. It is primarily related to the forward extension of the face relative to the auricular region ("facial forwardness"); however, it also measures general facial size. In contrast to the male Component I, this component does not measure upper facial flatness.

GOL	.551	NLB	.411	NAR	.763
BNL	.694	SOS	.414	SSR	.884
BBH	.424	FMB	.403	PRR	.850
BPL	.740	EKB	.448	ZOR	.835
NHL	.445	FRC	.407	ZMR	.769

II. Vault breadth and frontal profile flatness. This is a poorly defined component accounting for 7.8% of the total variation. It appears to be primarily related to the breadth of the cranial vault; however, it also measures the flatness of the frontal in the sagittal profile (refer to Figure 3, p. 18).

XCB	.684	FRC	.528
XFB	.810	FRS	.689
STB	.842	FRA	-.572

III. Prognathism. This component expresses the prognathism of the alveolar region (refer to Figure 1, p. 16). It accounts for 7.2% of the total variation. Although this component is similar to the

TABLE 11. LARSON SITE ARIKARA FEMALES VARIMAX ROTATED PRINCIPAL COMPONENT MATRIX.

VARIABLE	CODE NAME	I	II	III	IV	V	VI	VII	VIII	IX	X	COMMUNALITY
1 GLAB-OCC L	GOL	0.551	0.102	-0.556	0.191	-0.046	0.208	-0.037	-0.102	0.050	0.133	0.737
2 BAS-NAS L	BNL	0.694	-0.004	-0.408	0.179	0.352	0.134	-0.033	-0.092	-0.105	0.210	0.887
3 BAS-BREG HT	BBH	0.424	0.311	-0.301	0.030	0.646	-0.008	-0.100	-0.025	0.238	0.223	0.905
4 MAX BR	XCB	0.125	0.664	0.012	0.360	-0.027	-0.183	0.018	0.014	-0.244	0.234	0.782
5 MAX FRONT BR	XFB	0.127	0.810	-0.084	0.136	0.200	0.005	-0.190	0.025	-0.067	0.125	0.801
6 BISTEPHANIC	STB	-0.019	0.842	-0.026	0.137	0.053	-0.008	-0.215	0.035	-0.118	-0.143	0.814
7 BIZYG BR	ZYB	0.299	0.264	0.033	0.727	0.169	0.029	0.054	0.210	-0.012	0.143	0.757
8 BIAURIC BR	AUB	0.307	0.265	-0.018	0.614	0.257	-0.034	0.209	0.205	-0.126	0.226	0.733
9 BAS-PROSTH	BPL	0.740	-0.063	0.394	0.088	0.240	0.023	-0.040	-0.051	-0.164	0.196	0.842
10 NAS-PROSTH	NPH	0.330	0.033	0.047	0.115	0.010	-0.004	-0.035	0.846	-0.033	-0.041	0.846
11 NASAL HT	NLH	0.445	-0.017	-0.182	0.064	0.093	-0.103	0.023	0.648	-0.101	-0.045	0.687
12 ORBIT HT	OBH	-0.091	-0.034	-0.168	0.303	0.332	0.075	0.052	0.357	-0.240	0.233	0.488
13 ORBIT BR	OBB	0.290	-0.015	-0.322	0.470	-0.011	0.231	0.040	0.243	-0.286	0.102	0.615
14 NASAL BR	NLB	0.411	0.066	-0.246	0.140	0.225	0.110	-0.151	-0.176	-0.069	-0.145	0.396
15 PALATE BR	MAB	0.277	0.299	0.223	0.247	0.264	0.231	0.138	0.307	0.205	0.207	0.597
16 MASTOID L	MDH	0.316	0.200	-0.074	0.300	-0.129	0.111	0.019	0.141	0.205	0.431	0.513
17 BIMAXILLARY	ZMB	0.149	0.028	0.317	0.462	0.239	0.437	-0.144	0.158	0.185	0.155	0.698
18 ZYGOMAX SUB	SSS	0.227	0.008	0.175	-0.668	0.263	0.308	0.074	0.151	-0.130	0.153	0.762
19 BIFRONTAL	FMB	0.403	0.126	-0.223	0.683	0.215	0.272	-0.021	0.134	-0.059	0.066	0.841
20 NAS-FR SUBT	NAS	0.190	-0.082	-0.209	0.101	-0.088	0.891	-0.053	-0.010	-0.107	0.077	0.919
21 BIORBITAL	EKB	0.448	0.131	-0.237	0.639	0.212	0.293	-0.015	0.113	-0.062	0.052	0.833
22 INTERORB	DKB	0.301	0.124	-0.061	0.405	0.284	0.404	-0.096	-0.282	0.217	-0.024	0.654
23 NAS-DAC SUB	NDS	0.354	0.111	0.015	0.045	-0.072	0.180	0.011	-0.061	-0.740	-0.105	0.740
24 CHEEK HT	WMH	0.217	0.149	0.085	0.283	-0.131	0.105	0.116	0.490	0.441	0.135	0.651
25 SUPRAORB PR	SOS	0.414	0.121	-0.152	0.156	0.001	0.095	0.160	-0.295	0.120	-0.266	0.440
26 GLABELLA PR	GLS	0.256	-0.195	-0.313	0.096	-0.087	-0.194	-0.118	-0.248	0.080	0.543	0.633
27 NAS-BREG C	FRC	0.407	0.528	-0.251	-0.054	-0.031	0.077	-0.035	0.062	0.286	0.439	0.844
28 NAS-BREG SUB	FRS	0.009	0.689	-0.103	-0.104	-0.278	-0.075	0.134	-0.012	0.505	-0.018	0.853
29 NAS FRACTION	FRF	0.072	0.062	0.015	0.042	-0.131	0.207	-0.117	-0.137	0.051	0.798	0.743
30 BREG-LAM C	PAC	0.345	0.258	-0.379	0.091	0.032	0.083	-0.584	0.128	0.110	-0.078	0.721
31 BREG-LAM SUB	PAS	0.164	0.039	0.020	0.047	0.186	0.132	-0.913	0.006	0.005	0.020	0.916
32 BREG FRACT	PAF	0.164	0.133	-0.127	0.055	-0.152	-0.179	-0.613	0.019	0.027	0.177	0.528
33 NASION RAD	NAR	0.763	0.131	-0.359	0.097	-0.148	0.240	-0.077	0.032	-0.141	0.167	0.872
34 SUBSPIN RAD	SSR	0.884	0.070	0.129	-0.121	0.125	0.092	-0.046	0.166	-0.118	0.111	0.898
35 PROSTH RAD	PRR	0.850	0.075	0.213	-0.029	0.093	0.100	-0.150	0.264	-0.103	-0.064	0.900
36 ZYGOORB RAD	ZOR	0.835	0.059	-0.140	0.191	-0.159	0.000	-0.220	0.124	0.030	0.070	0.852
37 ZYGOMAX RAD	ZMR	0.769	-0.042	-0.105	0.374	-0.082	-0.051	-0.211	0.036	-0.077	-0.007	0.805
38 NAS ANG B-P	NAA	0.069	-0.115	0.860	-0.109	-0.070	-0.115	-0.010	-0.308	-0.041	0.010	0.884
39 PROSTH ANG	PRA	0.123	0.039	-0.820	0.097	0.217	0.151	0.011	-0.332	0.030	0.117	0.930
40 BAS ANG N-P	BAA	-0.218	0.028	0.061	0.011	-0.236	-0.022	-0.005	0.872	0.056	-0.189	0.938
41 NAS ANG B-B	NBA	-0.103	0.092	0.022	-0.043	0.846	-0.172	-0.115	-0.014	0.232	-0.160	0.859
42 BAS ANG N-B	BBA	-0.134	0.291	0.124	-0.127	-0.793	0.063	0.094	0.140	0.100	0.267	0.877
43 ZYGOMAX ANG	SSA	-0.163	0.011	-0.019	0.838	-0.139	-0.110	-0.132	-0.072	0.207	-0.078	0.833
44 NAS-FR ANG	NFA	-0.056	0.124	0.180	0.103	0.179	-0.881	0.055	0.039	0.086	-0.060	0.886
45 NAS-DAC ANG	NDA	-0.134	-0.045	-0.048	0.165	0.224	0.047	-0.062	-0.112	0.807	0.074	0.782
46 FRONTAL ANG	FRA	0.150	-0.572	0.022	0.092	0.299	0.136	-0.188	0.016	-0.448	0.298	0.792
47 PARIETAL ANG	PAA	-0.020	0.091	-0.234	0.013	-0.206	-0.123	0.806	0.095	0.048	-0.072	0.788
EIGENVALUE		7.333	3.645	3.405	4.505	3.249	2.822	2.722	3.333	2.687	2.309	
PERCENT OF TRACE		15.602	7.756	7.245	9.585	6.913	6.005	5.792	7.091	5.718	4.913	

previous prognathism components, the absence of loadings for prosthion radius (PRR) and subspinale radius (SSR) is conspicuous. These variables load on Component I.

GOL	-.556	NAA	.860
BNL	-.408	PRA	-.820
BPL	.394		

IV. <u>Facial breadth and flatness.</u> This component accounts for 9.6% of the total variation. The highest loading is on subspinale angle (SSA) which measures the flatness of the maxillary region relative to the bimaxillary diameter. The rest of the loadings are primarily related to facial breadth. This component differs from Component V of the Australian females in that it measures flatness only of the subnasal region and not of the face as a whole.

DKB	.405	AUB	.614
OBB	.470	ZMB	.462
EKB	.639	SSS	-.668
FMB	.683	SSA	.838
ZYB	.727		

V. <u>Vault height.</u> This is a simple and well defined component measuring cranial vault height (refer to Figure 2, p. 17). It accounts for 6.9% of the total variation.

BBH	.646	BBA	-.793
NBA	.846		

VI. <u>Upper facial flatness.</u> Distinct from Component IV, which measures subnasal flatness, this component measures the flatness of the

upper face. Specifically, it measures the flatness of the supraorbital region through the nasio-frontal angle (NFA) and nasio-frontal subtense (NAS). It accounts for 6.0% of the total variation.

DKB	.404	NAS	.891
ZMB	.437	NFA	-.881

VII. Parietal size and profile. This component has consistently appeared in all four groups. It measures the size and sagittal profile of the parietal (refer to Figure 3, p. 18) and accounts for 5.8% of the total variation.

PAC	-.584	PAF	-.613
PAS	-.913	PAA	.806

VIII. Facial height. This is another component that appears in more or less similar form among all the groups. It measures the vertical height of the face (refer to Figure 1, p. 16). It accounts for 7.1% of the total variation.

NPH	.846	PRA	-.382
NLH	.648	BAA	.872
WMH	.490		

IX. Interorbital prominence. This is a somewhat nebulous component, accounting for 5.7% of the total variation. The highest loadings are on naso-dacryal angle (NDA) and naso-dacryal subtense (NDS) which measure the relative positions of the roof of the nose to the plane of the eyes. However, there are additional loadings on the frontal subtense (FRS) and frontal angle (FRA) which measure the flatness of the frontal in the sagittal profile (refer to Figure 3, p. 18).

The patterning of negative and positive signs suggests that this component measures the prominence of the interorbital region relative to the flatness of the frontal. It is related to—but distinct from—Component VI, which concentrates more on the transverse flatness of the upper face. The loading of cheek height (WMH) on this component defies explanation.

NDS	-.740	FRS	.505
NDA	.807	FRA	-.448
WMH	.441		

X. <u>Frontal length.</u> This is a very poorly defined component. It accounts for 4.9% of the total variation. The loadings appear to concentrate on the length of the frontal in the sagittal plane. It is somewhat similar to Component II in that it deals with frontal length, but Component II also expresses the flatness of the frontal in the sagittal plane.

FRC	.489	GLS	.543
FRF	.798	MDH	.431

Component Structure Comparison

Larson Arikara versus Murray River males. The matrix of cosines indicating the degree of similarity between the component structures of the Arikara males and the Australian males is given in Table 12. Some interesting patterns of association are present. It should be noted that the negative correlations on certain of the following values result from sign reversals on the loadings of the two components.

TABLE 12. LARSON ARIKARA VS. MURRAY RIVER MALES COSINES AMONG COMPONENT AXES.

LARSON SITE ARIKARA	MURRAY RIVER AUSTRALIAN									
	I	II	III	IV	V	VI	VII	VIII	IX	X
	FACIAL FORWRD	CRANIAL BRDTH	MIDFACE PROMIN	PARIETL SIZ,PRF	PROG-NATHSM	FRONTL FLATNS	FACIAL HEIGHT	VAULT HEIGHT	INTORB PROMIN	FRONTL LENGTH
1 FACIAL SIZE,PROJ	0.5562	0.2311	0.1548	0.1550	0.3472	-0.0227	-0.0649	0.1622	0.6470	0.1380
2 CRANIAL BREADTH	-0.0428	0.9497	-0.1098	0.0129	-0.0397	0.1465	-0.0075	-0.0914	-0.2117	-0.0859
3 FACIAL HEIGHT	-0.0788	0.0065	0.0347	0.2492	-0.0999	-0.1362	-0.8828	0.3190	-0.1039	-0.0849
4 INTERORB PROMIN	-0.2028	0.0166	-0.6595	-0.1119	-0.2327	-0.1401	-0.0386	-0.0246	0.5454	-0.2882
5 VAULT HEIGHT	0.3065	-0.1073	-0.0902	0.1143	0.3384	-0.1510	-0.1881	-0.6629	-0.1675	-0.4831
6 PARIETAL SIZ,PRFL	0.1772	-0.0043	-0.0122	-0.9105	0.1857	0.1304	-0.2513	0.1316	-0.0688	-0.0673
7 FRONTAL LENGTH	0.0941	0.0081	-0.2392	-0.0774	-0.1431	-0.1001	-0.2551	-0.4809	-0.0048	0.7750
8 PROGNATHISM	0.6779	-0.0356	-0.0596	-0.0019	-0.6758	-0.0685	0.0987	0.1137	-0.1667	-0.1321
9 FRNTL PROFL FLAT	0.0703	-0.1608	-0.1469	0.1650	-0.0520	0.9404	-0.1442	-0.0903	0.0667	-0.0266
10 SUBNASAL FLATNS	-0.2046	0.0750	0.6193	-0.1677	-0.4308	0.0400	-0.1340	-0.3931	0.3946	-0.1614

First of all, certain components correlate very well between the two groups. The Australian cranial breadth component (II) has a high correlation (0.9497) with the Arikara cranial breadth component (2). The Australian parietal component (IV) correlates well (-0.9105) with the Arikara parietal component (6). The Australian frontal flatness component (VI), which expresses the flatness of the frontal in both the sagittal and transverse planes, correlates well (0.9404) with the Arikara frontal profile flatness component (9). The Australian facial height component (VII) has a high correlation (-0.8828) with the Arikara facial height component (3).

The remaining components do not present such a clear picture of associations. The Australian facial forwardness component (I) correlates primarily with the Arikara prognathism component (8), but it also correlates with the Arikara facial size and projection component (1) and to a lesser degree with the Arikara vault height component (5). The Australian midfacial prominence component (III) correlates equally with the Arikara interorbital prominence (4) and subnasal flatness (10) components. The Australian prognathism component (V) correlates primarily with the Arikara facial size and projection (1) and vault height (5) components. The Australian vault height component (VIII) has the highest correlation with the Arikara vault height component (5) but it also correlates with the Arikara facial height (3), frontal length (7) and subnasal flatness (10) components. The Australian interorbital prominence component (IX) correlates with the Arikara interorbital prominence component (4), but it has a higher

correlation with the Arikara facial size and projection component (1); it also has a moderate correlation with the Arikara subnasal flatness component (10). The Australian frontal length component (X) correlates fairly well with the Arikara frontal length component (7), but it also correlates with the Arikara vault height component (5).

Although it should be kept in mind that the name of a component is more of a mnemonic device than an absolute definition of the component, these results indicate that the component structure of the Australian males differs from that of the Arikara males primarily in terms of the structuring of the prominence of the face. Those components expressing the structuring of the cranial vault (cranial breadth, parietal size and profile, frontal flatness) do not differ substantially between the two groups. However, the components dealing with facial prominence (e.g., facial forwardness, midfacial prominence, prognathism, interorbital prominence, facial size and projection, subnasal flatness) do not correlate very well between the two groups. Also, the facial height components of the two groups correlate very well, whereas the vault height components do not.

The diagonal test vector (Table 13) indicates that the majority of the variables behave in a similar manner in the component structures of the two populations. Most of the variables that do not correlate well between the two populations have a low communality in one or both of the populations (e.g., STB, OBH, NLB, MAB, MDH, GLS). This indicates that the information contained in these variables is fairly independent of the common structuring of the variables. The fact that these

TABLE 13. LARSON ARIKARA VS. MURRAY RIVER MALES TEST VECTOR AND ORIGINAL COMMUNALITIES.

VARIABLE		CODE NAME	TEST VECTOR	ORIGINAL COMMUNALITY	
				ARIKARA	AUSTRALIAN
1	GLAB-OCC L	GOL	0.7393	0.7570	0.8146
2	BAS-NAS L	BNL	0.8953	0.8811	0.8625
3	BAS-BREG HT	BBH	0.8383	0.7526	0.9112
4	MAX BR	XCB	0.7416	0.7052	0.8172
5	MAX FRONT BR	XFB	0.8690	0.6849	0.7259
6	BISTEPHANIC	STB	0.4903	0.4523	0.6557
7	BIZYG BR	ZYB	0.8086	0.7739	0.7717
8	BIAURIC BR	AUB	0.7350	0.7687	0.7855
9	BAS-PROSTH	BPL	0.8972	0.9178	0.9292
10	NAS-PROSTH	NPH	0.9128	0.9193	0.9157
11	NASAL HT	NLH	0.6709	0.7743	0.8044
12	ORBIT HT	OBH	0.4884	0.6640	0.4707
13	ORBIT BR	OBB	0.5054	0.6591	0.7274
14	NASAL BR	NLB	0.3723	0.4799	0.6703
15	PALATE BR	MAB	0.4254	0.4315	0.6091
16	MASTOID L	MDH	0.4324	0.4542	0.6485
17	BIMAXILLARY	ZMB	0.4038	0.6682	0.6955
18	ZYGOMAX SUB	SSS	0.7893	0.8708	0.8447
19	BIFRONTAL	FMB	0.9166	0.8621	0.8806
20	NAS-FR SUBT	NAS	0.7377	0.9027	0.8690
21	BIORBITAL	EKB	0.9575	0.9014	0.9372
22	INTERORB	DKB	0.6786	0.6084	0.8140
23	NAS-DAC SUB	NDS	0.6635	0.7789	0.7195
24	CHEEK HT	WMH	0.8342	0.6870	0.7353
25	SUPRAORB PR	SOS	0.3398	0.6777	0.6945
26	GLABELLA PR	GLS	0.5002	0.6844	0.4307
27	NAS-BREG C	FRC	0.8957	0.7617	0.9013
28	NAS-BREG SUB	FRS	0.9021	0.8764	0.8838
29	NAS FRACTION	FRF	0.7844	0.7671	0.8222
30	BREG-LAM C	PAC	0.8579	0.6294	0.8340
31	BREG-LAM SUB	PAS	0.8919	0.9033	0.9085
32	BREG FRACT	PAF	0.8018	0.7660	0.6664
33	NASION RAD	NAR	0.8497	0.7456	0.8829
34	SUBSPIN RAD	SSR	0.8907	0.8402	0.9146
35	PROSTH RAD	PRR	0.9055	0.9338	0.9405
36	ZYGOORB RAD	ZOR	0.8394	0.7561	0.8764
37	ZYGOMAX RAD	ZMR	0.8164	0.8859	0.8444
38	NAS ANG B-P	NAA	0.8708	0.8598	0.9517
39	PROSTH ANG	PRA	0.8663	0.8855	0.9501
40	BAS ANG N-P	BAA	0.8762	0.9604	0.8917
41	NAS ANG B-B	NBA	0.8009	0.8551	0.8896
42	BAS ANG N-B	BBA	0.9667	0.9369	0.9140
43	ZYGOMAX ANG	SSA	0.7963	0.8300	0.9210
44	NAS-FR ANG	NFA	0.6299	0.8805	0.8622
45	NAS-DAC ANG	NDA	0.8022	0.8951	0.9295
46	FRONTAL ANG	FRA	0.9051	0.8482	0.8308
47	PARIETAL ANG	PAA	0.7847	0.7850	0.7977

variables do not correlate well between the two populations is not surprising. However, although orbital breadth (OBB), bimaxillary breadth (ZMB) and supraorbital projection (SOS) have fairly high communalities in both populations, they do not correlate very well between the populations. This suggests that these variables have a different "meaning" in terms of the cranial structuring of these two populations.

Larson Arikara versus Murray River females. An analysis of the similarity of the component structures between the females of the two groups reveals a different pattern of results than the male comparison (Table 14).

Two sets of components have high correlations between the two populations: the Australian facial height component (II) with the Arikara facial height component (8), and the Australian parietal size and profile component (VI) with the Arikara parietal size and profile component (7).

A second group of components displays a less precise degree of similarity. The Australian facial forwardness component (I) correlates highly with the Arikara facial size and projection component (1), but it also has a moderate correlation with the Arikara prognathism component (3). The Australian prognathism component (III) correlates most highly with the Arikara prognathism component (3) but it also correlates with the Arikara facial size and projection component (1). The Australian facial flatness component (V) has a high correlation with

TABLE 14. LARSON ARIKARA VS. MURRAY RIVER FEMALES COSINES AMONG COMPONENT AXES.

	MURRAY RIVER AUSTRALIAN									
	I	II	III	IV	V	VI	VII	VIII	IX	X
LARSON SITE ARIKARA	FACIAL FORWRD	FACIAL HEIGHT	PROG-NATHSM	FRONTL PROFL	FACIAL FLATNS	PARIETL SIZ,PRF	FRONTL LENGTH	FACIAL BRDTH	CRANIAL SIZE	MIDFACE PROMIN
1 FACIAL SIZE,PROJ	0.8583	0.0950	0.3908	-0.0439	0.0121	0.0285	-0.0102	-0.2494	0.0557	0.1832
2 VAULT BR + FRNTL	-0.1622	0.1187	-0.0081	-0.6599	0.0524	0.1457	0.0835	-0.1004	0.6661	0.1997
3 PROGNATHISM	-0.4307	0.0235	0.8351	-0.0199	0.2283	-0.0189	-0.0086	-0.0968	-0.1857	0.1554
4 FACE BR & FLATNS	-0.1059	0.1159	-0.1672	0.2709	0.3852	0.0753	0.0436	-0.7837	0.1342	-0.3029
5 VAULT HEIGHT	-0.0459	-0.1994	0.1721	0.1923	-0.2060	-0.1296	-0.8132	-0.0146	0.4105	-0.1435
6 UP FACE FLATNS	-0.1191	0.0014	0.1401	-0.0759	-0.8454	0.0095	0.2399	-0.3827	-0.0686	-0.1901
7 PARIETAL SIZ,PRFL	-0.0101	-0.0132	-0.0670	-0.1090	0.0514	-0.9483	0.1485	-0.1262	0.0132	0.0838
8 FACIAL HEIGHT	-0.0411	0.9314	0.0425	0.1988	-0.1025	-0.1044	-0.0910	0.1879	0.1193	-0.0590
9 INTERORB PROMIN	0.1404	-0.0181	0.2157	-0.3049	0.1529	-0.0552	0.1025	0.2375	0.0168	-0.8627
10 FRONTAL LENGTH	0.0065	-0.2051	0.1711	0.5502	-0.0229	-0.0269	0.5359	0.2257	0.5538	-0.0129

the Arikara upper facial flatness component (6), but it also has a moderate correlation with the Arikara facial breadth and flatness component (4). The Australian facial breadth component (VIII) has a fairly substantial correlation with the Arikara facial breadth and flatness component (4) but it also correlates with the Arikara upper facial flatness component. The Australian midfacial prominence component (X) has a high correlation with the Arikara interorbital prominence component (9) and a moderate correlation with the Arikara facial breadth and flatness component (4).

A third set of components does not correlate very well between the two populations. The Australian frontal profile flatness component (IV) has moderate correlations with the Arikara vault breadth and frontal transverse flatness component (2), the Arikara frontal length component (10), and the Arikara interorbital prominence component (9). The Australian frontal length component (VII) has a moderate correlation with the Arikara frontal length component (10), but it has a higher correlation with the Arikara vault height component (5). The Australian cranial size component (IX), which is somewhat of a "catch all" component, correlates with the Arikara vault breadth and transverse frontal flatness component (2), the Arikara frontal length component (10), and the Arikara vault height component (5).

These results indicate that the Arikara and Australian females are fairly similar in terms of the structuring of the face and most of the structuring of the vault. They differ primarily in terms of the structuring of the frontal. That the Australian cranial size component

correlates with so many of the Arikara components is not surprising since it is a very generalized "catch all" component.

The males, on the other hand, differ primarily in terms of the structuring of the face.

The diagonal test vector (Table 15) indicates that virtually all of the variables behave in a very similar manner in the component structures of the two populations. This is true even for the variables with low communalities in one or both of the populations (e.g., OBH, MAB, MDH, DKB, NDS, WMH, SOS, PAF). Nasal breadth (NLB) has a very low communality in both populations and a very low correlation between populations. However, although bimaxillary breadth (ZMB) has a fairly high communality in both populations, it does not correlate very well between them. This was also true for the males.

Summary. Overall, these results indicate that there is a much better degree of fit between the component structures of the females of the two groups. The males differ primarily in terms of the structuring of facial prominence. In both sexes, bimaxillary breadth tends to have a different "meaning" in the component structures of the two groups. This is also true for orbital breadth (OBB) and supraorbital projection (SOS) for the males

Analysis of Principal Component Scores

Fourteen principal components with eigenvalues greater than 1.0 were extracted from the Arikara-Australian pooled within-groups correlation matrix (Tables A-1 and A-2, Appendix) and were rotated

TABLE 15. LARSON ARIKARA VS. MURRAY RIVER FEMALES
TEST VECTOR AND ORIGINAL COMMUNALITIES.

VARIABLE		CODE NAME	TEST VECTOR	ORIGINAL COMMUNALITY	
				ARIKARA	AUSTRALIAN
1	GLAB-OCC L	GOL	0.9245	0.7370	0.8511
2	BAS-NAS L	BNL	0.9224	0.8869	0.8461
3	BAS-BREG HT	BBH	0.8897	0.9048	0.8639
4	MAX BR	XCB	0.7488	0.7622	0.7541
5	MAX FRONT BR	XFB	0.8805	0.8009	0.8434
6	BISTEPHANIC	STB	0.8557	0.8138	0.7208
7	BIZYG BR	ZYB	0.8680	0.7573	0.8069
8	BIAURIC BR	AUB	0.8518	0.7327	0.7909
9	BAS-PROSTH	BPL	0.8189	0.8422	0.7787
10	NAS-PROSTH	NPH	0.8575	0.8462	0.9107
11	NASAL HT	NLH	0.7668	0.6868	0.7611
12	ORBIT HT	OBH	0.6880	0.4877	0.6544
13	ORBIT BR	OBB	0.6925	0.6147	0.7428
14	NASAL BR	NLB	0.1011	0.3957	0.5209
15	PALATE BR	MAB	0.8544	0.5973	0.5980
16	MASTOID L	MDH	0.6015	0.5130	0.7137
17	BIMAXILLARY	ZMB	0.5352	0.6884	0.7422
18	ZYGOMAX SUB	SSS	0.7764	0.7615	0.8877
19	BIFRONTAL	FMB	0.9190	0.8406	0.8720
20	NAS-FR SUBT	NAS	0.9089	0.9193	0.8696
21	BIORBITAL	EKB	0.9072	0.8327	0.9427
22	INTERORB	DKB	0.8204	0.6541	0.5589
23	NAS-DAC SUB	NDS	0.6824	0.7402	0.5197
24	CHEEK HT	WMH	0.6349	0.6509	0.5929
25	SUPRAORB PR	SOS	0.7837	0.4404	0.5718
26	GLABELLA PR	GLS	0.6039	0.6334	0.6118
27	NAS-BREG C	FRC	0.9050	0.8440	0.8585
28	NAS-BREG SUB	FRS	0.9336	0.8527	0.8590
29	NAS FRACTION	FRF	0.8818	0.7428	0.7077
30	BREG-LAM C	PAC	0.7577	0.7214	0.8713
31	BREG-LAM SUB	PAS	0.9204	0.9163	0.9388
32	BREG FRACT	PAF	0.8446	0.5280	0.7049
33	NASION RAD	NAR	0.9078	0.8718	0.9262
34	SUBSPIN RAD	SSR	0.9545	0.8980	0.8962
35	PROSTH RAD	PRR	0.9280	0.9004	0.9128
36	ZYGOORB RAD	ZOR	0.8397	0.8519	0.8708
37	ZYGOMAX RAD	ZMR	0.7447	0.8051	0.8749
38	NAS ANG B-P	NAA	0.8526	0.8844	0.9277
39	PROSTH ANG	PRA	0.8346	0.9295	0.9523
40	BAS ANG N-P	BAA	0.8790	0.9079	0.9002
41	NAS ANG B-B	NBA	0.8615	0.8593	0.8528
42	BAS ANG N-B	BBA	0.9345	0.8770	0.8799
43	ZYGOMAX ANG	SSA	0.8723	0.8326	0.9270
44	NAS-FR ANG	NFA	0.8646	0.8859	0.8219
45	NAS-DAC ANG	NDA	0.9105	0.7818	0.8464
46	FRONTAL ANG	FRA	0.8807	0.7922	0.8846
47	PARIETAL ANG	PAA	0.7211	0.7877	0.8295

via the VARIMAX criterion (Table 16). Together, these 14 components account for 82.06% of the total variation. Principal components scores were calculated for each individual on each component, and group means were tested for homogeneity via a two-way Multivariate Analysis of Variance (MANOVA). Both sex and group effects were examined (Table A-3, Appendix). The group means on each component, and the F-values for sex effects, group effects, and the sex-group interaction are given in Table 17.

I. Facial forwardness. This component measures the extension of the face relative to the auricular region. It accounts for 12.84% of the total variation. There are marked group and sex differences on this component. The Murray River males have the most extended faces, followed by the Murray River females, Larson males and Larson females (Table 17).

GOL	.582	SSR	.810
BNL	.758	PRR	.717
BPL	.631	ZOR	.887
NAR	.802		

II. Midfacial breadth. This component accounts for 6.14% of the total variation. It measures the transverse breadth of the midfacial region. The F-values (Table 17) indicate that the group differences on this component are on the same order of magnitude as sex differences within a group. The component means indicate that the Arikara males have the broadest midfacial regions, and the Australian females have the narrowest midfacial regions. The Australian males and the Arikara females are nearly identical in terms of midfacial breadth.

TABLE 16. ARIKARA-AUSTRALIAN WITHIN-GROUPS VARIMAX ROTATED PRINCIPAL COMPONENT MATRIX.

	VARIABLE	CODE NAME	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	COM
1	GLAB-OCC L	GOL	0.60	0.12	-0.04	-0.13	0.12	0.00	0.17	0.03	0.29	-0.02	0.15	0.28	0.18	0.33	0.77
2	BAS-NAS L	BNL	0.76	0.19	-0.10	-0.22	-0.15	-0.07	0.18	0.21	0.14	-0.12	0.06	0.14	0.18	-0.09	0.87
3	BAS-BREG HT	BBH	0.24	0.07	-0.05	-0.23	0.04	0.08	-0.03	0.77	0.31	0.02	0.31	0.03	0.01	0.09	0.92
4	MAX BR	XCB	0.04	0.17	0.09	-0.04	0.05	-0.05	-0.26	0.00	0.19	-0.04	0.72	0.19	0.18	0.03	0.74
5	MAX FRONT BR	XFB	0.06	0.16	0.09	-0.01	0.15	0.13	-0.06	0.06	0.18	0.05	0.81	0.12	0.05	-0.06	0.79
6	BISTEPHANIC	STB	-0.01	-0.00	0.03	0.03	0.17	0.06	0.13	0.08	0.02	-0.02	0.82	0.03	-0.14	0.07	0.76
7	BIZYG BR	ZYB	0.21	0.60	0.01	-0.10	-0.03	-0.02	-0.21	-0.02	0.05	-0.04	0.29	0.40	0.22	0.11	0.77
8	BIAURIC BR	AUB	0.12	0.54	0.03	-0.15	-0.01	-0.05	-0.32	0.04	0.10	-0.06	0.34	0.29	0.33	0.05	0.75
9	BAS-PROSTH	BPL	0.63	0.16	-0.07	0.62	-0.16	-0.05	0.09	-0.01	0.09	-0.05	0.06	0.08	0.06	-0.09	0.89
10	NAS-PROSTH	NPH	0.20	0.06	0.89	0.13	-0.07	-0.05	0.06	0.01	0.03	-0.09	0.07	0.12	0.07	0.03	0.90
11	NASAL HT	NLH	0.22	0.04	0.79	-0.10	-0.06	-0.02	-0.01	-0.02	0.05	-0.01	0.10	0.03	0.27	-0.15	0.79
12	ORBIT HT	OBH	0.01	0.09	0.27	-0.12	-0.10	-0.04	0.05	-0.06	-0.09	-0.00	0.02	0.07	0.74	0.14	0.69
13	ORBIT BR	OBB	0.23	0.02	0.15	0.04	-0.10	0.03	0.14	-0.00	-0.01	0.00	0.08	0.84	0.08	0.06	0.84
14	NASAL BR	NLB	0.37	0.07	-0.04	0.14	-0.14	0.04	0.04	-0.05	0.20	0.12	-0.19	0.15	-0.05	-0.43	0.48
15	PALATE BR	MAB	0.14	0.46	0.31	0.18	0.08	-0.21	-0.06	0.21	0.26	0.01	0.08	0.06	0.02	0.01	0.54
16	MASTOID L	MDH	0.03	0.29	0.27	0.15	-0.12	-0.02	-0.03	0.05	0.35	-0.01	0.22	0.19	-0.09	0.26	0.49
17	BIMAXILLARY	ZMB	0.12	0.82	0.02	0.11	0.03	0.10	0.03	0.04	0.11	0.08	-0.05	0.12	-0.11	0.01	0.77
18	ZYGOMAX SUB	SSS	0.06	0.02	0.21	0.37	0.30	0.03	0.48	0.34	0.10	-0.22	-0.25	-0.06	0.30	-0.26	0.91
19	BIFRONTAL	FMB	0.32	0.38	0.09	-0.03	-0.06	0.07	0.17	0.01	-0.01	0.14	0.30	0.67	0.08	-0.10	0.87
20	NAS-FR SUBT	NAS	0.22	0.03	0.02	-0.04	-0.15	0.02	0.87	-0.09	0.01	0.03	0.03	0.26	0.02	0.07	0.92
21	BIORBITAL	EKB	0.33	0.44	0.09	-0.03	-0.11	0.04	0.11	-0.02	0.01	0.15	0.29	0.67	0.07	-0.10	0.91
22	INTERORB	DKB	0.38	0.58	-0.09	-0.08	-0.04	0.03	0.25	-0.11	-0.05	0.33	0.26	-0.04	-0.03	-0.23	0.60
23	NAS-DAC SUB	NDS	0.22	0.11	0.03	-0.07	-0.09	0.03	0.10	-0.07	0.00	-0.89	0.09	-0.07	0.01	-0.05	0.91
24	CHEEK HT	WMH	0.17	0.34	0.42	0.04	-0.09	-0.03	-0.06	0.04	0.33	0.12	0.06	-0.03	-0.43	0.16	0.69
25	SUPRAORB PR	SOS	0.23	0.16	-0.10	-0.03	0.28	0.01	0.27	0.12	0.05	0.07	-0.05	0.46	-0.29	-0.01	0.56
26	GLABELLA PR	GLS	0.13	0.02	-0.14	-0.10	-0.13	0.12	-0.20	-0.08	0.61	0.07	-0.30	0.34	-0.11	-0.08	0.73
27	NAS-BREG C	FRC	0.21	0.04	0.04	-0.10	0.35	-0.05	0.05	0.02	0.70	-0.00	0.41	-0.01	0.06	0.09	0.85
28	NAS-BREG SUB	FRS	-0.00	-0.01	-0.06	-0.06	0.88	-0.02	-0.11	-0.09	0.17	0.08	0.26	-0.07	-0.03	0.06	0.91
29	NAS FRACTION	FRF	0.06	0.10	0.01	-0.03	-0.08	0.07	0.06	-0.03	0.79	-0.05	0.17	-0.11	-0.07	-0.02	0.71
30	BREG-LAM C	PAC	0.31	0.11	0.03	-0.08	-0.00	0.46	0.17	0.18	0.14	0.06	0.18	0.05	0.08	0.57	0.79
31	BREG-LAM SUB	PAS	0.08	0.06	-0.02	-0.01	-0.02	0.95	0.01	0.10	0.04	0.02	0.07	0.02	-0.02	0.18	0.96
32	BREG FRACT	PAF	0.18	-0.04	-0.01	0.04	0.16	0.51	0.11	0.04	0.08	-0.05	0.13	0.04	0.07	0.54	0.66
33	NASION RAD	NAR	0.80	0.10	0.07	-0.19	0.09	0.05	0.28	-0.11	0.09	-0.07	0.06	0.18	0.10	0.05	0.86
34	SUBSPIN RAD	SSR	0.81	0.11	0.15	0.29	0.08	0.02	0.18	0.19	0.02	-0.12	-0.08	0.06	0.10	-0.06	0.88
35	PROSTH RAD	PRR	0.72	0.10	0.24	0.50	-0.01	0.02	0.19	0.14	0.03	-0.05	0.03	0.12	-0.00	0.00	0.92
36	ZYGORB RAD	ZOR	0.89	0.09	0.09	-0.01	0.02	0.05	-0.03	-0.04	-0.01	0.10	0.02	0.14	-0.12	0.01	0.86
37	ZYGOMAX RAD	ZMR	0.86	0.03	0.01	-0.02	-0.14	0.08	-0.20	-0.09	-0.05	0.04	0.06	0.11	-0.14	0.09	0.86
38	NAS ANG B-P	NAA	0.06	0.01	-0.36	0.88	-0.02	0.03	-0.07	-0.18	-0.04	0.09	-0.01	-0.06	-0.08	-0.04	0.97
39	PROSTH ANG	PRA	0.13	0.03	-0.36	-0.85	-0.01	-0.01	0.07	0.23	0.08	-0.06	-0.01	0.02	0.09	-0.02	0.95
40	BAS ANG N-P	BAA	-0.24	-0.05	0.93	-0.04	0.03	-0.01	-0.02	-0.03	-0.07	-0.03	0.03	0.03	-0.00	0.10	0.94
41	NAS ANG B-B	NBA	-0.21	-0.04	-0.03	-0.12	-0.10	0.17	-0.17	0.86	-0.14	0.07	0.09	-0.03	-0.12	0.10	0.92
42	BAS ANG N-B	BBA	-0.18	-0.07	0.11	0.14	0.36	-0.12	0.05	-0.69	0.44	-0.00	0.15	-0.04	0.00	0.05	0.92
43	ZYGOMAX ANG	SSA	-0.01	0.33	-0.20	-0.31	-0.28	0.02	-0.44	-0.30	-0.05	0.25	0.22	0.11	-0.33	0.26	0.90
44	NAS-FR ANG	NFA	-0.13	0.08	0.00	0.04	0.15	0.01	-0.90	0.10	-0.02	-0.00	0.05	-0.09	0.01	-0.11	0.90
45	NAS-DAC ANG	NDA	0.07	0.26	-0.08	0.01	0.06	0.00	0.06	-0.01	-0.03	0.93	0.08	0.03	-0.02	-0.10	0.98
46	FRONTAL ANG	FRA	0.09	0.05	0.09	-0.02	-0.88	0.00	0.14	0.10	0.20	-0.09	-0.11	0.06	0.07	-0.04	0.89
47	PARIETAL ANG	PAA	0.08	-0.01	0.04	-0.04	0.03	-0.93	0.09	-0.03	0.04	0.01	0.02	0.02	0.06	0.11	0.90
	EIGENVALUE		6.03	2.88	3.30	2.87	2.41	2.43	2.88	2.41	2.50	2.09	3.13	2.66	1.53	1.44	
	PERCENT OF TRACE		12.84	6.14	7.02	6.11	5.12	5.17	6.13	5.12	5.31	4.44	6.66	5.66	3.27	3.07	

TABLE 17. ARIKARA-AUSTRALIAN WITHIN-GROUPS COMPONENT SCORE MEANS AND F-VALUES.

COMPONENT	COMPONENT SCORE MEANS				F-VALUES *		
	AUSTRALIAN MALES	AUSTRALIAN FEMALES	ARIKARA MALES	ARIKARA FEMALES	SEX	GROUP	SEX*GROUP
1 FACIAL FORWARDNESS	1.469	0.225	-0.310	-1.197	66.47	136.29	1.70
2 MIDFACIAL BREADTH	-0.035	-1.406	1.334	-0.022	92.17	100.91	0.00
3 FACIAL HEIGHT	-0.943	-1.464	1.517	0.658	20.24	279.36	1.52
4 PROGNATHISM	0.868	0.770	-0.885	-0.594	0.14	129.19	2.01
5 FRONTL PRFL FLATNS	0.404	0.496	-0.412	-0.390	0.03	38.57	0.07
6 PARIETAL SIZE,PRFL	-0.058	-0.232	0.356	-0.082	4.93	4.21	0.93
7 FULL FACIAL FLATNS	-0.540	0.008	0.154	0.329	7.30	13.65	1.84
8 VAULT HEIGHT	-0.311	-0.606	0.690	0.146	8.30	40.89	0.82
9 FRONTAL LENGTH	0.955	-0.560	0.410	-0.753	96.46	7.21	1.65
10 INTERORB PROMIN	-0.377	0.093	-0.399	0.728	31.66	5.79	5.00
11 VAULT BREADTH	-0.868	-1.068	0.840	0.875	0.00	176.49	0.68
12 UPPER FACE BRDTH	1.212	0.021	0.005	-1.090	74.87	71.46	0.12
13 NOISE (ORBIT HT)	-0.385	-0.644	0.560	0.362	1.94	50.62	0.05
14 NOISE (PARIETAL)	0.819	0.398	-0.576	-0.525	2.47	71.37	2.96

* F(0.05, / 1,120 /) = 3.92

ZYB	.566	EKB	.440
AUB	.542	DKB	.578
MAB	.460	ZMB	.832

III. Facial height. This component measures the vertical height of the face (refer to Figure 1, p. 16). It accounts for 7.02% of the total variation. The F-values indicate that group differences on this component far outweigh any sex differences within a group (Table 17). According to the component means, the Australians have much lower faces than the Arikara.

NPH	.892	BAA	.929
NLH	.786	WMH	.417

IV. Prognathism. This component accounts for 6.11% of the total variation. It measures the prognathism of the alveolar region. There are virtually no sex differences on this component, but the group differences are substantial. The means indicate that the Australians are much more prognathic than the Arikara (Table 17).

BPL	.619	NAA	.876
PRR	.504	PRA	-.846

V. Frontal profile flatness. This component measures the flatness of the frontal in the sagittal profile (refer to Figure 3, p. 18). It accounts for 5.12% of the total variation. There are no sex differences on this component and group differences are moderate. The means indicate that the Arikara have flatter frontals than the Australians (Table 17).

FRS	.880	FRA	-.876

VI. Parietal size and profile flatness. This component measures the size and flatness of the parietal in the sagittal plane. It accounts for 5.17% of the total variation. There are only minor sex and group differences on this component (Table 17).

PAC	.458	PAF	.510
PAS	.949	PAA	-.933

VII. Full facial flatness. This component measures the flatness of the face, both in the supraorbital and subnasal regions. It accounts for 6.13% of the total variation. The F-values indicate that there are both sex and group differences on this component, but they are minor differences in terms of the differences shown by other components. The means indicate that the Australians have slightly flatter faces than the Arikara (Table 17).

SSS	.482	SSA	-.440
NAS	.866	NFA	-.900

VIII. Vault height. The loadings on this component indicate that it measures the relative height of the cranial vault (refer to Figure 2, p. 17). It accounts for 5.12% of the total variation. The sex differences on this component are not very substantial compared with the group differences. The means indicate that the Australians have lower cranial vaults than the Arikara.

BBH	.777	BBA	-.690
NBA	.864		

IX. Frontal length. This component measures the length of the frontal in the sagittal profile. It accounts for 5.31% of the total

variation. The F-values indicate that the sex differences on this component far outweigh the group differences. The means indicate that the males of both groups have longer frontals than the females (Table 17).

GLS	.609	FRF	.787
FRC	.696	BBA	.441

X. Interorbital prominence. This component accounts for 4.44% of the total variation and measures the prominence of the roof of the nasal saddle relative to the plane of the eyes. The higher the naso-dacryal angle (NDA), the more recessed this region is in this regard. The sex differences on this component are substantially greater than the group differences. In fact, this is the only component with a significant sex-group interaction. This means that there is a group difference in sexual dimorphism on this component. An examination of the means indicates that the Larson female mean is much greater than any of the others (Table 17). This indicates that the interorbital region is recessed in these specimens. The Australian females also have recessed interorbital regions, but to a lesser degree. It may be interesting to examine this region in other populations to determine if there is a consistent sexual difference.

NDS	-.894	NDA	.932

XI. Vault breadth. Accounting for 6.66% of the total variation, this component measures the transverse breadth of the cranial vault. The F-values show substantial group differences on this component, but no sex differences. The means indicate that the Arikara have wider vaults than the Australians (Table 17).

XCB	.716	STB	.820
XFB	.806	FRC	.413

XII. Upper facial breadth. Distinct from both the midfacial breadth component (II) and the vault breadth component (XI), this component measures the transverse breadth of the orbital region. It accounts for 5.66% of the total variation. The F-values indicate that both sex and group differences on this component are substantial. According to the means, the Australian males have the widest upper facial breadths, the Arikara females have the narrowest breadths, and the Australian females and Arikara males have nearly identical breadths (Table 17).

ZYB	.403	EKB	.669
OBB	.836	SOS	.459
FMB	.667		

XIII. Noise (orbit height). The odd patterning of loadings on this component indicates that it is probably related to residual variation in the matrix. It accounts for 3.27% of the total variation. It seems to draw a contrast between orbital height (OBH) and cheek height (WMH). Sex and group differences on this component probably have no real meaning.

OBH	.739	WMH	-.431

XIV. Noise (Parietal). This also appears to be a noise component, expressing residual variation in the matrix. It accounts for 3.07% of the total variation. The highest loadings are on parietal chord (PAC) and parietal fraction (PAF). However, due to the extreme cohesiveness

of the parietal in all of the previous analyses, these loadings probably have little meaning. Similarly, group differences on this component probably have no biological reality.

NLB	-.427	PAC	.569
PAF	.542		

Summary. The results of the analysis of principal components scores may be briefly summarized as follows:

1. The groups and sexes differ only slightly in parietal size and flatness.
2. There are sex differences in the length of the frontal, but only minor group differences. The males of both groups have longer frontals. The groups differ moderately in frontal flatness, with the Arikara having flatter frontals.
3. The group differences far outweigh the sex differences in facial height, prognathism, vault breadth and vault height. The Australians are much more prognathic, and have much lower faces, much narrower cranial vaults, and lower cranial vaults.
4. Sex and group differences are essentially on the same order of magnitude for midfacial breadth and upper facial breadth. However, there is an interesting patterning to these differences which will be discussed in detail later.
5. The groups and the sexes differ slightly in facial flatness, with the Australian males having the flattest faces.
6. Group differences in facial forwardness are more substantial than sex differences, with the Australians having the most extended faces.

7. The Arikara females have a more recessed interorbital region. This is also true to a lesser extent for the Australian females.
8. Finally, the groups differ substantially on the noise components, but these differences probably have little meaning.

V. INTERPRETATIONS

Prognathism and Facial Forwardness

In spite of a great deal of within-group sex difference, the Australians have much more extended faces than the Arikara (Table 17, p. 64). Hylander (1977), in an excellent study of Eskimo cranio-facial morphology, suggests that the major adaptive value of Eskimo facial flatness is to increase their masticatory efficiency. He found that the flatness of the Eskimo face is apparently due to a more anterior positioning of the postorbital bar and the anterior root of the zygoma, rather than a depression of the midsagittal region (1977: 135). A similar interpretation is given by Oschinsky (1962: 365). Although the Australians have only slightly flatter faces than the Arikara (refer to Table 17, p. 64), their faces are extended in much the same manner as the Eskimos. Thus their faces are positioned more anteriorally relative to the auricular region and the temporomandibular joint. The anterior positioning of the postorbital bar (reflected by zygoorbitale radius (ZOR) on Component I) places the temporalis muscle, particularly the anterior portions, in a more anterior position and increases its mechanical efficiency (Hylander 1977: 148).

A similar situation occurs with the masseter muscle. As the anterior root of the zygomatic is moved anteriorally (reflected by zygomaxillary radius (ZMR) on Component I), its moment arm increases, thus increasing its mechanical efficiency (Hylander 1977: 149).

In a selective regime that places a premium on large teeth, it is entirely logical that selection would also favor efficient muscles of mastication. The forward extension of the Australian face is thus a very adaptive feature.

Oddly enough, the high degree of alveolar prognathism exhibited by the Australians (Table 17, p. 64) appears to be counterproductive in this regard. It positions the teeth, particularly the anterior teeth, quite forward of the positions of the masticatory muscles. This produces unfavorable bending moments in the face (Hylander 1977: 155) and requires more energy for the generation of equal amounts of force during the loading of the anterior dentition than in less prognathic populations.

Smith (1976: 135) and Brose and Wolpoff (1971: 1176) suggest that one function of alveolar prognathism in the Neandertals may be to accommodate the large roots of their anterior dentition, and Smith (1976) has shown that, in fact, Neandertal anterior tooth roots are significantly larger than those of modern Amerindians. It may be that the Australians are prognathic because of selection to maintain large tooth size in spite of the biomechanical inefficiency that results from accommodating these large teeth.

The component structure comparison showed that the Australians and the Arikara males differed primarily in terms of the structuring of midfacial prominence. It is quite possible that the Australians illustrate restructuring in this region to dissipate the bending moments produced by this prognathism. Of course, the females did not

exhibit marked differences in facial structuring even though the female Australians are nearly as prognathic as the males (Table 17, p. 64). This suggests that this region of the face probably exhibits a more complex pattern than the model presented here.

Brow Ridges and Cranio-facial Breadths

There is an interesting pattern of differences between the two groups relative to cranio-facial breadths. Both sexes of the Arikara have substantially wider cranial vaults than the Australians. This is also true for midfacial breadth, although there is a great deal of within-group sexual variation (Table 17, p. 64). Yet, in terms of upper facial breadth (Component XII), the Australians are substantially wider than the Arikara (although there is a great deal of within-group sexual difference on this component). Thus the Australians have narrower cranial vaults, narrower midfacial regions, yet wider upper facial regions. This morphological feature is obvious upon a visual examination of an Australian skull, the orbital region appears almost mask-like in relation to the rest of the face.

Endo's (1966) studies on the mechanical significance of the facial skeleton indicate that the face resembles a rigid frame structured to resist bending moments produced by masticatory forces. He notes that the intensity of masticatory force acting on a facial structure is responsible for the thickness and breadth of that structure (Endo 1966: 75). His studies indicate that the most intensive stresses appear on the lateral margins and infero-lateral border of the eye orbits, the

nasal region, and the lateral part of the supraorbital margin (1966: 50). These stresses are even more intensified with loading of the anterior teeth (1966: 50).

The wide, massive orbital regions of the Australians may be an adaptation to resist bending moments produced by masticatory stress. This is especially true in light of their high degree of alveolar prognathism, which probably intensifies these bending moments (Hylander 1977: 155), and their definite orientation toward utilization of the anterior dentition in rather stressful nonmasticatory activities (cf. Gould 1968).

The prominent brow ridges of the Australians, as indicated by supraorbital projection (SOS) and glabellar projection (GLS) in Tables 4 and 5, pp. 21, 22, may be a combination of two factors. Endo's studies (1966: 100) indicate that a vertical forehead resists the bending moment placed on it by its total height, while an inclined (flat) forehead can only resist this bending moment with its inferior border, necessitating a reinforcement in the glabellar region. Moss and Young's study (1960) of the functional significance of the brow ridge presents a slightly different picture. They suggest that the supraorbital ridge functions to fill the gap between the anterior lobe of the brain and the eye orbit (Moss and Young 1960: 285-287).

These two views of the function of the supraorbital ridge are not necessarily mutually exclusive and may be integrated in terms of the problem at hand. Although the Arikara have flatter frontals than the Australians (Table 17, p. 64), the high degree of prognathism and

extensive use of the teeth probably results in greater stresses being generated in the Australian face. Their large brow ridges may have formed to reinforce the inferior margin of the frontal to resist these stresses. Also, given the prominence of the Australian face in conjunction with a low cranial vault and a wide, massive orbital region, another function of the large supraorbital ridge could certainly be to bridge the gap between the brain case and the orbital region. A similar suggestion has been made by Smith (1976) for Neandertals.

Vertical Facial Height

Table 17 (p. 64) indicates that the Australians have substantially lower faces than the Arikara. Hunt (1960) in a study of facial growth based on 49 skulls from the Murray River region in Australia, suggests that the vigorous chewing practiced by the Australians retards the vertical growth of the face while encouraging the lateral growth of the face. He bases his conclusions on the relative activity of the median palatine suture and cites studies based on rats as supportive evidence (Hunt 1960: 249). This suggestion may be called upon to explain the low faces of the Australians, although it has been criticized by Hylander. Hylander (1977: 157) suggests that a higher face is better able to resist masticatory stress and thus would be more adaptive in a population that practices vigorous chewing.

These two viewpoints can possibly be reconciled through recent research by Guglielmino-Matessi, Gluckman and Cavalli-Sforza (1979). These researchers attempted to correlate the factors and discriminant

functions from Howells' (1973) analysis of worldwide craniometric variation with various climatic variables. They found that vertical facial height has a strong correlation with temperature, the groups living in the coldest climates having the highest faces. This would explain the facial height differences between the Australians and the Eskimos, but probably not between the Australians and the Arikara.

Interorbital Prominence

Suzuki (1956), in an investigation of Japanese skulls from the Neolithic (Jomon Period) to modern times, suggests that the prominence of the nasal root may be related to occlusal type. He found that the prehistoric skulls, with a labidont occlusal type, have a wide, prominent interorbital area, whereas the skulls of historical age, with a stegodont occlusal type, have a flat nasal root. An explanation of the recessed nature of the interorbital region of the Larson females in this manner (and to a lesser extent, the Murray River females) would require that they maintained a different type of occlusion than the males of the same population. This is possible, but unlikely. This anatomical feature probably has some other meaning not clearly discernible.

VI. CONCLUSIONS

The previous analyses can be divided into two phases: an examination of the similarity of the component structures of the two groups, and an examination of metrical differences between the groups along the more generalized structural dimensions common to both groups.

The first phase of the analysis is very difficult to interpret, probably because of a lack of experience with the analytical technique on my part. It may be fruitful to examine the similarities in the component structures between males and females of the same population, or between two groups more closely related than the Arikara and the Australians, to get a better appreciation of what the values in the matrix of cosines mean.

The second phase of the analysis produced much more concrete results. The functional explanations I present for these differences should certainly not be considered as the last word on the subject. Still, I believe they are entirely plausible.

Interestingly enough, most of the morphological features that seem to be functionally related to tooth size in the Australians are also some of the more obvious features of the cranio-facial complex exhibited by the Neandertals (see Brose and Wolpoff, 1971, or Smith, 1976, for example). It might be interesting to examine Neandertal cranio-facial morphology in light of their tooth size.

Finally, I believe that to get a precise, fine-grained appreciation of the functional relationships between cranio-facial variables and

tooth size, one must examine them simultaneously within the same population. This study took a more indirect approach because of the lack of an adequate data source. I hope in the future to rectify this situation.

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APPENDIX

TABLE A-1. ARIKARA-AUSTRALIAN WITHIN-GROUPS CORRELATION MATRIX, SECTION 1.

VARIABLE	GOL	BNL	BBH	XCB	XFB	STB	ZYB	AUB	BPL	NPH	NLH	OBH	OBB	NLB	MAB	MDH	ZMB	SSS	FMB	NAS	EKB	DKB	NDS	WMH
GOL	1.00	0.64	0.36	0.29	0.25	0.17	0.37	0.30	0.38	0.19	0.16	0.16	0.39	0.26	0.18	0.30	0.22	0.07	0.47	0.33	0.47	0.32	0.18	0.18
BNL		1.00	0.45	0.13	0.17	0.05	0.35	0.30	0.58	0.13	0.21	0.14	0.33	0.32	0.21	0.06	0.23	0.13	0.45	0.36	0.47	0.39	0.29	0.13
BBH			1.00	0.28	0.34	0.28	0.23	0.26	0.07	0.04	0.06	0.01	0.10	0.11	0.23	0.19	0.14	0.06	0.24	0.01	0.21	0.13	0.08	0.15
XCB				1.00	0.67	0.49	0.50	0.63	0.05	0.15	0.21	0.10	0.18	0.14	0.22	0.37	0.12	-0.17	0.33	-0.13	0.35	0.17	0.04	0.17
XFB					1.00	0.69	0.40	0.43	0.10	0.14	0.16	0.03	0.18	0.14	0.21	0.28	0.17	-0.07	0.40	-0.03	0.41	0.28	-0.00	0.23
STB						1.00	0.18	0.22	0.04	0.09	0.06	-0.03	0.09	0.07	0.11	0.13	0.06	-0.07	0.22	0.08	0.20	0.18	0.05	0.13
ZYB							1.00	0.78	0.18	0.16	0.16	0.19	0.39	0.14	0.32	0.33	0.45	-0.16	0.57	0.05	0.64	0.37	0.08	0.20
AUB								1.00	0.10	0.12	0.23	0.21	0.25	0.05	0.34	0.28	0.35	-0.14	0.45	-0.08	0.49	0.26	0.05	0.19
BPL									1.00	0.27	0.12	-0.00	0.26	0.38	0.24	0.13	0.29	0.26	0.33	0.25	0.35	0.31	0.18	0.17
NPH										1.00	0.74	0.31	0.29	0.09	0.32	0.31	0.13	0.25	0.26	0.15	0.26	0.03	0.16	0.37
NLH											1.00	0.38	0.21	0.13	0.30	0.16	0.04	0.19	0.23	0.10	0.25	0.08	0.15	0.27
OBH												1.00	0.17	-0.04	0.09	0.03	0.01	0.09	0.21	0.12	0.17	0.03	0.11	-0.13
OBB													1.00	0.17	0.16	0.20	0.19	0.04	0.70	0.41	0.74	0.08	0.01	0.10
NLB														1.00	0.22	0.16	0.20	0.03	0.35	0.14	0.37	0.34	0.07	0.09
MAB															1.00	0.37	0.33	0.14	0.27	0.03	0.31	0.13	0.02	0.36
MDH																1.00	0.23	-0.04	0.26	0.08	0.31	0.16	0.05	0.34
ZMB																	1.00	0.11	0.41	0.09	0.45	0.44	-0.00	0.35
SSS																		1.00	-0.01	0.27	-0.05	-0.04	0.16	-0.06
FMB																			1.00	0.43	0.93	0.53	0.04	0.20
NAS																				1.00	0.37	0.27	0.10	0.03
EKB																					1.00	0.57	0.04	0.24
DKB																						1.00	0.04	0.17
NDS																							1.00	-0.05
WMH																								1.00
SOS																								
GLS																								
FRC																								
FRS																								
FRF																								
PAC																								
PAS																								
PAF																								
NAR																								
SSR																								
PRR																								
ZOR																								
ZMR																								
NAA																								
PRA																								
BAA																								
NBA																								
BBA																								
SSA																								
NFA																								
NDA																								
FRA																								
PAA																								

TABLE A-2. ARIKARA-AUSTRALIAN WITHIN-GROUPS CORRELATION MATRIX, SECTION 2.

VARIABLE	SOS	GLS	FRC	FRS	FRF	PAC	PAS	PAF	NAR	SSR	PRR	ZOR	ZMR	NAA	PRA	BAA	NBA	BBA	SSA	NFA	NDA	FRA	PAA
GPL	0.34	0.25	0.47	0.17	0.19	0.60	0.16	0.31	0.64	0.46	0.43	0.50	0.45	-0.14	0.24	-0.13	-0.17	0.02	0.03	-0.22	0.05	0.02	0.15
BNL	0.26	0.21	0.25	-0.12	0.17	0.27	0.03	0.10	0.73	0.59	0.51	0.60	0.53	-0.20	0.45	-0.31	-0.10	-0.37	-0.02	-0.26	0.00	0.26	0.12
BBH	0.16	0.08	0.53	0.16	0.29	0.38	0.23	0.20	0.19	0.24	0.19	0.18	0.18	-0.30	0.40	-0.11	0.69	-0.40	0.01	0.06	0.04	0.07	-0.06
XCB	0.06	-0.02	0.42	0.23	0.21	0.17	0.04	0.07	0.17	0.02	0.04	0.12	0.11	-0.12	0.04	0.09	0.02	0.17	0.21	0.23	0.06	-0.05	0.05
XFB	0.07	-0.03	0.46	0.32	0.26	0.24	0.17	0.20	0.17	0.07	0.10	0.13	0.08	-0.03	0.03	0.06	0.05	0.15	0.13	0.14	0.17	-0.15	-0.03
STB	0.14	-0.14	0.36	0.30	0.15	0.23	0.12	0.25	0.08	-0.02	0.07	0.05	0.01	-0.03	-0.02	0.05	0.10	0.13	0.09	-0.02	0.06	-0.19	-0.01
ZYB	0.20	0.11	0.34	0.04	0.13	0.22	0.07	0.10	0.31	0.22	0.19	0.30	0.32	-0.12	0.13	-0.01	-0.04	-0.03	0.34	0.12	0.15	0.08	0.04
AUB	0.10	0.11	0.27	0.06	0.11	0.16	0.05	0.04	0.23	0.12	0.06	0.21	0.21	-0.18	0.18	-0.01	0.00	-0.01	0.28	0.23	0.11	0.07	0.03
BPL	0.16	0.11	0.11	-0.13	0.13	0.10	0.00	0.07	0.42	0.66	0.79	0.50	0.48	0.61	-0.41	-0.27	-0.28	-0.10	-0.12	-0.16	0.05	0.20	0.06
NPH	0.01	-0.06	0.12	-0.10	0.05	0.11	-0.04	0.04	0.24	0.31	0.47	0.22	0.14	-0.23	-0.41	0.82	-0.11	0.04	-0.18	-0.08	-0.11	0.18	0.11
NLH	-0.07	-0.05	0.13	-0.06	0.09	0.06	-0.04	0.01	0.25	0.28	0.26	0.19	0.16	-0.32	-0.16	0.61	-0.10	0.03	-0.16	-0.04	-0.05	0.14	0.04
OBH	-0.11	-0.11	0.01	-0.09	-0.07	0.09	-0.04	0.08	0.10	0.07	0.05	-0.06	-0.01	-0.23	0.04	0.26	-0.07	-0.03	-0.08	-0.06	-0.06	0.10	0.11
OBB	0.27	0.16	0.07	-0.12	0.00	0.20	0.08	0.17	0.40	0.29	0.34	0.34	0.27	-0.07	-0.01	0.10	-0.08	-0.07	0.05	-0.24	0.04	0.17	0.03
NLB	0.16	0.16	0.17	-0.04	0.10	0.09	0.02	-0.05	0.25	0.26	0.32	0.30	0.31	0.17	-0.05	-0.17	-0.14	0.02	0.05	-0.05	0.15	0.14	0.03
MAB	0.07	0.04	0.27	0.13	0.19	0.08	-0.09	-0.03	0.17	0.28	0.32	0.19	0.11	-0.00	-0.12	0.16	0.01	0.03	-0.00	0.05	0.03	0.02	0.16
MDH	0.09	0.14	0.29	0.01	0.23	0.25	0.12	0.07	0.14	0.13	0.25	0.14	0.10	-0.04	-0.13	0.22	0.00	0.13	0.13	-0.02	0.05	0.13	-0.01
ZMB	0.24	0.16	0.13	0.02	0.17	0.20	0.13	0.07	0.19	0.22	0.25	0.23	0.14	0.09	-0.06	-0.04	-0.02	-0.05	0.32	0.03	0.27	0.07	-0.04
SSS	0.12	-0.12	0.04	0.00	0.01	0.01	-0.02	0.03	0.16	0.48	0.40	0.02	-0.22	0.10	-0.20	0.13	-0.02	-0.03	-0.90	-0.30	-0.15	0.01	0.04
FMB	0.37	0.15	0.20	-0.01	0.08	0.28	0.13	0.09	0.46	0.35	0.41	0.41	0.34	-0.06	0.05	0.00	-0.06	-0.09	0.19	-0.18	0.29	0.12	0.01
NAS	0.29	-0.02	0.08	-0.18	0.07	0.23	0.08	0.12	0.47	0.31	0.33	0.22	0.11	-0.07	0.09	-0.04	-0.22	-0.01	-0.21	-0.96	0.08	0.23	0.05
EKB	0.35	0.16	0.20	-0.06	0.09	0.27	0.10	0.07	0.47	0.34	0.39	0.43	0.37	-0.06	0.06	-0.01	-0.10	-0.08	0.25	-0.13	0.31	0.17	0.04
DKB	0.28	0.03	0.16	0.03	0.10	0.17	0.04	0.02	0.38	0.29	0.30	0.39	0.30	0.04	0.10	-0.19	-0.14	-0.05	0.23	-0.14	0.58	0.06	0.05
NDS	-0.05	-0.04	0.08	-0.10	0.11	0.06	0.00	0.09	0.23	0.25	0.19	0.08	0.14	-0.11	0.10	0.01	-0.12	-0.02	-0.16	-0.08	-0.79	0.16	0.03
WMH	0.10	0.21	0.24	-0.00	0.32	0.19	0.06	0.07	0.13	0.19	0.25	0.28	0.22	-0.06	-0.14	0.25	-0.02	0.08	0.20	0.03	0.14	0.14	0.04
SOS	1.00	0.19	0.15	0.10	0.03	0.16	0.06	0.16	0.32	0.28	0.27	0.27	0.21	-0.02	0.10	-0.13	-0.03	-0.03	-0.02	-0.20	0.19	-0.05	0.04
GLS		1.00	0.18	-0.07	0.34	0.06	0.09	0.06	0.13	0.02	0.01	0.17	0.16	-0.02	0.15	-0.20	-0.12	0.07	0.18	0.07	0.05	0.20	-0.07
FRC			1.00	0.54	0.56	0.27	0.04	0.20	0.31	0.19	0.18	0.18	0.13	-0.14	0.14	-0.01	-0.10	0.52	0.01	-0.03	0.03	-0.13	0.11
FRS				1.00	0.15	0.05	-0.01	0.14	0.05	-0.06	-0.09	-0.01	-0.08	0.00	0.02	-0.03	-0.08	0.44	-0.01	0.18	0.11	-0.93	0.04
FRF					1.00	0.15	0.09	0.12	0.14	0.06	0.06	0.07	0.08	-0.02	0.07	-0.06	-0.08	0.30	0.06	-0.06	-0.03	0.20	-0.02
PAC						1.00	0.63	0.60	0.38	0.25	0.25	0.28	0.29	-0.14	0.15	-0.00	0.17	-0.12	0.03	-0.16	0.06	0.07	-0.22
PAS							1.00	0.52	0.13	0.08	0.10	0.12	0.16	0.00	0.05	-0.04	0.24	-0.17	0.09	-0.03	0.03	0.03	-0.39
PAF								1.00	0.26	0.16	0.16	0.18	0.15	-0.00	0.02	-0.01	0.09	0.01	0.00	-0.10	-0.06	-0.06	-0.29
NAR									1.00	0.68	0.59	0.75	0.61	-0.19	0.28	-0.12	-0.33	-0.01	-0.06	-0.37	0.04	0.03	0.07
SSR										1.00	0.86	0.72	0.64	0.18	-0.10	-0.09	-0.12	-0.15	-0.36	-0.23	-0.01	0.14	0.04
PRR											1.00	0.66	0.57	0.34	-0.36	0.03	-0.13	-0.10	-0.27	-0.23	0.04	0.17	0.03
ZOR												1.00	0.83	0.02	0.09	-0.13	-0.19	-0.12	0.08	-0.11	0.19	0.09	0.01
ZMR													1.00	0.09	0.06	-0.18	-0.12	-0.15	0.27	-0.01	0.08	0.14	-0.03
NAA														1.00	-0.69	-0.40	-0.20	0.15	-0.06	0.06	0.12	-0.06	-0.08
PRA															1.00	-0.38	0.19	-0.31	0.17	-0.09	-0.02	0.04	0.03
BAA																1.00	0.04	0.16	-0.14	0.04	-0.13	0.03	0.04
NBA																	1.00	-0.66	0.02	0.22	0.01	0.34	-0.21
BBA																		1.00	0.00	-0.03	-0.02	-0.25	0.15
SSA																			1.00	0.29	0.27	0.03	-0.06
NFA																				1.00	-0.01	-0.21	-0.06
NDA																					1.00	-0.11	0.00
FRA																						1.00	0.01
PAA																							1.00

TABLE A-3. MANOVA SUMMARY TABLE FOR COMPONENT SCORE COMPARISON.

VARIABLE	SOURCE	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROBABILITY
FACIAL FORWARDNESS						
	SEX	1	66.450	66.450	66.47	0.0001
	GROUP	1	136.262	136.262	136.29	0.0001
	SEX*GROUP	1	1.697	1.697	1.70	0.1941
	ERROR	210	209.950	1.000		
MIDFACIAL BREADTH						
	SEX	1	92.164	92.164	92.17	0.0001
	GROUP	1	100.898	100.898	100.91	0.0001
	SEX*GROUP	1	0.003	0.003	0.00	0.9531
	ERROR	210	209.983	1.000		
FACIAL HEIGHT						
	SEX	1	20.237	20.237	20.24	0.0001
	GROUP	1	279.379	279.379	279.36	0.0001
	SEX*GROUP	1	1.520	1.520	1.52	0.2190
	ERROR	210	210.016	1.000		
PROGNATHISM						
	SEX	1	0.135	0.135	0.14	0.7134
	GROUP	1	129.199	129.199	129.19	0.0001
	SEX*GROUP	1	2.009	2.009	2.01	0.1579
	ERROR	210	210.010	1.000		
FRONTAL PREL FLATNS						
	SEX	1	0.029	0.029	0.03	0.8566
	GROUP	1	38.579	38.579	38.57	0.0001
	SEX*GROUP	1	0.067	0.067	0.07	0.7965
	ERROR	210	210.033	1.000		

TABLE A-3. CONTINUED

VARIABLE	SOURCE	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROBABILITY
PARIETAL SIZE,PRFL						
	SEX	1	4.926	4.926	4.93	0.0275
	GROUP	1	4.211	4.211	4.21	0.0414
	SEX*GROUP	1	0.929	0.929	0.93	0.3363
	ERROR	210	210.008	1.000		
FULL FACIAL FLATNS						
	SEX	1	7.300	7.300	7.30	0.0075
	GROUP	1	13.650	13.650	13.65	0.0003
	SEX*GROUP	1	1.845	1.845	1.84	0.1758
	ERROR	210	209.999	1.000		
VAULT HEIGHT						
	SEX	1	8.303	8.303	8.30	0.0044
	GROUP	1	40.896	40.896	40.89	0.0001
	SEX*GROUP	1	0.821	0.821	0.82	0.3659
	ERROR	210	210.021	1.000		
FRONTAL LENGTH						
	SEX	1	96.465	96.465	96.46	0.0001
	GROUP	1	7.210	7.210	7.21	0.0078
	SEX*GROUP	1	1.646	1.646	1.65	0.2009
	ERROR	210	210.005	1.000		
INTERORB PROMIN						
	SEX	1	31.661	31.661	31.66	0.0001
	GROUP	1	5.790	5.790	5.79	0.0170
	SEX*GROUP	1	5.003	5.003	5.00	0.0264
	ERROR	210	210.018	1.000		

TABLE A-3. CONTINUED

VARIABLE	SOURCE	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROBABILITY
VAULT BREACTH						
	SEX	1	0.001	0.001	0.00	0.9763
	GROUP	1	176.489	176.489	176.49	0.0001
	SEX*GROUP	1	0.677	0.677	0.68	0.4114
	ERROR	210	209.997	1.000		
UPPER FACE BRDTH						
	SEX	1	74.873	74.873	74.87	0.0001
	GROUP	1	71.463	71.463	71.46	0.0001
	SEX*GROUP	1	0.122	0.122	0.12	0.7368
	ERROR	210	210.008	1.000		
NOISE (ORBIT HT)						
	SEX	1	1.943	1.943	1.94	0.1648
	GROUP	1	50.616	50.616	50.62	0.0001
	SEX*GROUP	1	0.050	0.050	0.05	0.8231
	ERROR	210	209.995	1.000		
NOISE (PARIETAL)						
	SEX	1	2.469	2.469	2.47	0.1176
	GROUP	1	71.371	71.371	71.37	0.0001
	SEX*GROUP	1	2.956	2.956	2.96	0.0870
	ERROR	210	209.993	1.000		

VITA

Patrick J. Key was born on July 3, 1954 in Williston, North Dakota. He graduated, magma cum laude, with Honors, from the University of North Dakota in 1976 with a major in Anthropology and minors in Geology and Humanities. He has participated in archaeological fieldwork in North Dakota, Montana, Minnesota and Wyoming.

His research interests center on human paleontology, skeletal biology, functional morphology, and human variation. He is a member of the Plains Anthropological Conference, the International Dermatoglyphics Association, and is a student member of the American Association of Physical Anthropologists. His non-academic interests are fictional writing, music, and photography.

He has also been employed as a carpenter, and a title abstracter and field representative for Key Oil Properties, Williston, North Dakota.