

Order Number 9512496

**Origins and biological affinities of the modern Thai population:
An osteological perspective**

Nakbunlung, Supaporn, Ph.D.

University of Illinois at Urbana-Champaign, 1994

U·M·I
300 N. Zeeb Rd.
Ann Arbor, MI 48106

**ORIGINS AND BIOLOGICAL AFFINITIES OF THE MODERN THAI
POPULATION: AN OSTEOLOGICAL PERSPECTIVE**

BY

SUPAPORN NAKBUNLUNG

B.A., Silpakorn University, 1976

M.A., Northern Illinois University, 1982

THESIS

**submitted in partial fulfillment of the requirements
for the degree of Doctor of Philosophy in Anthropology
in the Graduate College of the
University of Illinois at Urbana-Champaign, 1994**

Urbana, Illinois

UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

THE GRADUATE COLLEGE

JULY 1994

WE HEREBY RECOMMEND THAT THE THESIS BY

SUPAPORN NAKBUNLUNG

ENTITLED ORIGINS AND BIOLOGICAL AFFINITIES
OF THE MODERN THAI POPULATION:
AN OSTEOLOGICAL PERSPECTIVE

BE ACCEPTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY

B. Banghien
Director of Thesis Research

Engene Riles
Head of Department

Committee on Final Examination†

Linda Disinger
Chairperson

James L. ...
M. L. ...

† Required for doctor's degree but not for master's.

© Copyright by Supaporn Nakbunlung, 1994

ABSTRACT

The work focuses on the assessment of population affinities based on craniofacial skeletal data. The main objective is to test the “immigrant” and “endogenous” hypotheses for the origin of the modern Thai. The former proposes that the ancestors of the modern Thai migrated from China during the early second millennium A.D., and the latter proposes that the modern Thai are descended from prehistoric inhabitants of present-day Thailand. Although there is a great deal of research on East and Southeast Asia using archaeological, linguistic, and genetic data, detailed analysis of skeletal morphology has not been attempted beyond a few preliminary studies.

Morphological comparisons among adult Thai and Chinese males and females, from both recent and archaeological populations, are made to assess biological distance among these groups. Both metric and discrete craniofacial traits are used. The compared features include fourteen metric traits: maximum cranial length, maximum cranial breadth, bizygomatic breadth, facial height, facial

breadth, nasal height, nasal breadth, orbital height, orbital breadth, biorbital breadth, interorbital breadth, and three malar bone measurements (frontomolare orbitale to superior zygomaxillare, frontomolare orbitale to inferior zygomaxillare, and superior zygomaxillare to inferior zygomaxillare). Ten discrete traits are used, including metopic suture, nasofrontal suture, Os japonica, infraorbital suture, infraorbital foramen, incisura malaris, subnasal character, shovel-shaped incisor, four-cusped molar, and rocker jaw.

Results of principal components analyses indicate that the craniofacial skeletal pattern changed through time. The early populations display larger craniofacial features than the modern sample population. Metric traits suggest that modern Thai are more closely related to archaeological Thai than to archaeological Chinese. Analysis of discrete traits, however, indicate that modern Thai and Chinese populations are very similar. Results of principal analyses also demonstrate that interorbital breadth is the best measure for differentiating these populations. Lastly, path analyses indicate that the primary ancestral groups for the modern Thai are not included in this study.

To my progenitors,
Vira Nakbunbh and Wilas (Bunnak) Nakbunbh,
and my progeny,
Ninin Nakbunlung

ACKNOWLEDGEMENTS

I wish to first acknowledge the inspiration of my former advisor, Dr. Geoffrey G. Pope, who encouraged me to pursue a doctoral degree. This task would not be accomplished without the help of my two current advisors, Drs. Linda Klepinger and R. Barry Lewis, whose patience in offering comments and suggestions during the formulation of this manuscript has been never ending. My research advisor, Dr. Lewis, has especially provided helpful guidance at all stages of the writing of this dissertation. I would also like to thank the other two members of my committee, Dr. Tim Futing Liao who supplied advice on statistical procedures, and Dr. F. Kris Lehman who has provided invaluable recommendations during the reading of this thesis.

I also extend my thanks to the following individuals and/or institutions for their cooperation during my visits to each research collection. Individual recognition is due Dr. Sood Sangvichien, Dr. Sanchai Sangvichien, Ms. Wattana Subhawan, and Mr. Somsak Pramankij at the Department of Anatomy, Faculty of Medical

Science, Mahidol University, Bangkok, Thailand; Dr. Bennet Bronson at the Field Museum of Natural History, Chicago; and Drs. Sheilagh and Richard Brooks at the University of Nevada, Las Vegas. The great hospitality of Drs. Brooks during my stay in Las Vegas also deserves mention here. I also thank the Thai Fine Art Department, Bangkok; the Department of Anatomy, Faculty of Medical Science, and the Faculty of Fine Arts, Chiang Mai University, Chiang Mai, Thailand; and the American Museum of Natural History, New York.

This dissertation was supported by the following funding sources: the Department of Anthropology and the Graduate College of the University of Illinois at Urbana-Champaign, the American Museum of Natural History, and Sigma Xi Grants-in-Aid of Research.

I am greatly indebted Dr. Deborah Bakken for her editorial assistance as well as for her suggestions and comments. I also would like to thank Ms. Agnes Loeffler for her helpful comments and advice. I wish to extend my thank to Ms. Jolee West, Ms. Kristin Hedman, Ms. Mary Nielubowsky, Ms. Rasmi Shoocongdej, Ms. Sibel Barut, Ms. Valerie Williams, Dr. Steve Mertens, and anonymous friends for their support during the completion of this research. Lastly, I would like to thank my husband, Bannarak, for his technical assistance in the preparation of the illustrations.

TABLE OF CONTENTS

LIST OF TABLES	xi
LIST OF FIGURES	xiv
INTRODUCTION	1
CHAPTER	
1. THE MIGRATIONS OF THAI POPULATIONS	5
Thai Migration Hypotheses	7
The Immigrant Hypothesis	8
The Endogenous Hypothesis	9
Previous Studies of Thai Affinities.	10
Cultural Evidence	10
Genetic Evidence	25
Dental and Skeletal Evidence	28
Conclusion	30
2. A BIOLOGICAL APPROACH TO MEASURING MIGRATIONS AND DESCENT.	35
Measures of Biological Distance	35
Morphological Approach	36
Selected Craniofacial Traits	40
Population Samples	42
Measuring Migrations and Descent	43
Principal Components Analysis	44
Path Coefficients	45
Conclusion	46
3. ANALYSIS OF BIOLOGICAL AFFINITIES OF THE MODERN THAI	49
Bilateral Symmetry of Thai and Chinese Crania	51
Grouped Comparisons of Craniofacial Metric Traits	53

Bilateral Symmetry of Six Discrete Traits	59
Grouped Comparisons of Dental and Facial Discrete Traits	61
The Influence of Associated Traits in Craniofacial Variation	61
Ancestral-Descendant Relationships of the Modern Thai .	69
 4. INTERPRETATION OF THE TEST RESULTS AND DISCUSSION OF THEIR IMPLICATIONS	106
Craniofacial Morphological Differences between Modern Thai and Other Groups	106
Craniofacial Morphological Differences between Archaeological Thai and Other Groups	110
The Patterns of Craniofacial Metric Trait Variation: Spatial and Chronological Aspects	112
Conclusion of The Test Results	115
The Implication of Craniofacial Morphological in Phylogenetic Reconstruction	115
 5. CONCLUSIONS	119
Future Research	124
Conclusion	125
 REFERENCES CITED	126
 APPENDIX	
I. DEFINITIONS AND ILLUSTRATIONS OF MORPHOLOGICAL LANDMARKS FOR THE CRANIOFACIAL METRIC AND DISCRETE TRAITS USED IN THIS STUDY	154
 II. DESCRIPTION AND GRAPHIC PRESENTATION OF BOXPLOTS USED IN MALE AND FEMALE COMPARISONS OF EACH POPULATION GROUP	161
 III. GRAPHIC PRESENTATION OF PRINCIPAL COMPONENTS ANALYSES	177

VITA	185
------------	-----

LIST OF TABLES

Table	Page
1. The Archaeological Evidence from the Selected Sites in Thailand	32
2. Thai and Chinese Skeletal Population Samples	47
3. Paired-Samples <i>t</i> tests between the Left and Right Sides of Male and Female Thai and Chinese Crania	74
4. Paired-Samples <i>t</i> tests between the Left and Right Sides of Male Thai and Chinese Crania	75
5. Paired-Samples <i>t</i> tests between the Left and Right Sides of Female Thai and Chinese Crania	76
6. Summary Descriptions of Craniofacial Metric Traits for Male and Female Modern and Archaeological Thai and Chinese Groups	77
7. Summary Descriptions of Craniofacial Metric Traits for Male Modern and Archaeological Thai and Chinese Groups.	79
8. Summary Descriptions of Craniofacial Metric Traits for Female Modern and Archaeological Thai and Chinese Groups	81
9. Summary Comparisons of Craniofacial Metric Traits for Modern and Archaeological Thai and Chinese Groups Using the Tukey HSD Multiple Comparison Tests	83

10.	Chi-Square Tests between the Left and Right Sides of Male Thai and Chinese Crania	84
11.	Chi-Square Tests between the Left and Right Sides of Female Thai and Chinese Crania	85
12.	Summary Comparisons of Discrete Traits for Archaeological Thai, Modern Thai, and Modern Chinese Groups	86
13.	Pearson Correlation Matrix for Male Craniofacial Metric Traits	87
14.	Pearson Correlation Matrix for Female Craniofacial Metric Traits	88
15.	Loading of Variables for the First Three Principal Components (Male)	89
16.	Loading of Variables for the First Three Principal Components (Female)	90
17.	Matrix of Pairwise Comparison Probabilities Using Tukey HSD Multiple Comparisons for Male "Overall Facial Feature"	91
18.	Matrix of Pairwise Comparison Probabilities Using Tukey HSD Multiple Comparisons for Male "Mid-Facial Feature"	92
19.	Matrix of Pairwise Comparison Probabilities Using Tukey HSD Multiple Comparisons for Female "Overall Facial Feature"	93
20.	Matrix of Pairwise Comparison Probabilities Using Tukey HSD Multiple Comparisons for Female "Mid-Facial Feature"	94

21.	Q-mode Correlation Matrix for Male and Female of the Four Population Samples	95
22.	Q-mode Correlation Matrix for Male of the Four Population Samples	96
23.	Q-mode Correlation Matrix for Female of the Four Population Samples	97
24.	Estimated Standardized Regression Coefficients for Male and Female Modern Thai and Modern Chinese	98
25.	Estimated Standardized Regression Coefficients for Male Modern Thai and Modern Chinese	99
26.	Estimated Standardized Regression Coefficients for Female Modern Thai and Modern Chinese	100

LIST OF FIGURES

Figure	Page
1. The Austro-Tai Language Family-Tree	33
2. Selected Archaeological Sites in Thailand and China	34
3. Path Diagram of Thai Origin	48
4. First and Second Component Scores Plots for Male Groups .	101
5. First and Second Component Scores Plots for Female Groups	102
6. Path Diagram of Thai Origin with Numerical Estimates of Path Coefficients (Male and Female)	103
7. Path Diagram of Thai Origin with Numerical Estimates of Path Coefficients (Male)	104
8. Path Diagram of Thai Origin with Numerical Estimates of Path Coefficients (Female)	105
9. Morphological Landmarks for the Craniofacial Metric Traits (Frontal View)	158
10. Morphological Landmarks for the Craniofacial Metric and Discrete Traits (Lateral View)	159
11. Morphological Landmarks for the Craniofacial Discrete Traits (Frontal View)	160

12.	Boxplot Comparisons of Maximum Cranial Length (g-op) for Male and Female of Each Population Group	163
13.	Boxplot Comparisons of Maximum Cranial Breadth (eu-eu) for Male and Female of Each Population Group	164
14.	Boxplot Comparisons of Facial Height (na-pr) for Male and Female of Each Population Group	165
15.	Boxplot Comparisons of Bizygomatic Breadth (zy-zy) for Male and Female of Each Population Group	166
16.	Boxplot Comparisons of Biorbital Breadth (fmo-fmo) for Male and Female of Each Population Group	167
17.	Boxplot Comparisons of Frontomale Orbitale to Superior Zygomaxillare (fmo-szm) for Male and Female of Each Population Group	168
18.	Boxplot Comparisons of Frontomale Orbitale to Inferior Zygomaxillare (fmo-izm) for Male and Female of Each Population Group	169
19.	Boxplot Comparisons of Superior Zygomaxillare to Inferior Zygomaxillare (szm-izm) for Male and Female of Each Population Group	170
20.	Boxplot Comparisons of Nasal Height (na-ns) for Male and Female of Each Population Group	171
21.	Boxplot Comparisons of Nasal Breadth (al-al) for Male and Female of Each Population Group	172
22.	Boxplot Comparisons of Orbital Height (orb-h) for Male and Female of Each Population Group	173
23.	Boxplot Comparisons of Orbital Breadth (orb-b) for Male and Female of Each Population Group	174

24.	Boxplot Comparisons of Interorbital Breadth (int-or) for Male and Female of Each Population Group	175
25.	Boxplot Comparisons of Facial Breadth (max-max) for Male and Female of Each Population Group	176
26.	First and Second Component Scores Plots for Male Archaeological Thai and Chinese Groups	177
27.	First and Second Component Scores Plots for Male Archaeological and Modern Thai Groups	178
28.	First and Second Component Scores Plots for Male Archaeological and Modern Chinese Groups	179
29.	First and Second Component Scores Plots for Male Modern Thai and Chinese Groups	180
30.	First and Second Component Scores Plots for Female Archaeological Thai and Chinese Groups	181
31.	First and Second Component Scores Plots for Female Archaeological and Modern Thai Groups	182
32.	First and Second Component Scores Plots for Female Archaeological and Modern Chinese Groups	183
33.	First and Second Component Scores Plots for Female Modern Thai and Chinese Groups	184

INTRODUCTION

The determination of population affinities based on skeletal remains is an important research area in biological anthropology. Human skeletal material may be used as direct evidence of biological distance between past and present populations. A number of comparative morphological studies focus on Southeast Asia, an area of population diversity (Dunn 1967; LeBar, et al. 1964;). Previous research on skeletal populations of Southeast Asia has revealed both similarities and differences among these ethnic groups (Brace, et al. 1991; Li, et al. 1991; Pietrusewsky 1978, 1981, 1993, 1994; Pietrusewsky, et al. 1992; Turner 1989, 1990). However, attempts to indicate ancestral-descendant relationships among groups are rarely made (Brace, et al. 1991; Li, et al. 1991; Pietrusewsky 1978, 1981, 1993, 1994; Pietrusewsky, et al. 1992; Turner 1989, 1990 also; but see Mizoguchi 1986 for an example involving the origin of the Japanese).

This dissertation examines the origins and biological affinities of modern Thai populations. The objective is to

investigate the biological relationships between modern and archaeological populations using craniofacial metric and nonmetric traits. For the purposes of this dissertation the word “Thai” refers only to native speakers of standard (central) Thai and speakers of all other languages of the Tai family currently living in Thailand. “Tai” is used to refer to Tai speakers other than Siamese-Tai or standard Thai speakers. By the term “early or archaeological populations in Thailand,” I mean any populations found in Thailand prior to the Historical period, which began in the mid thirteenth century at the time of the establishment of the Sukhothai Kingdom, the so-called first sovereign state in Thailand.

This research tests the hypothesis that the modern Thai are descended from the Han-Chinese (the sample does not include minority groups for either population). The pattern of craniofacial variation among Thai and Chinese populations from different time periods is examined in order to answer the following questions: (1) Are there important differences or similarities between Thai and Chinese archaeological and recent populations?; (2) If there are significant differences between them, what traits or associated traits characterize those differences?; (3) If they are closely related, what are the implications underlying this relationship?; and (4) How useful are facial characteristics as a method for

establishing phylogenetic relationships for other populations? In short, this research examines past and present skeletal populations to assess population affinities among four groups: archaeological Thai, archaeological Chinese, modern Thai, and modern Chinese.

This paper is organized into five chapters. Chapter 1 describes the status of previous studies on the problem of determining the affinities of Southeast Asian populations. It presents historical, linguistic, and archaeological evidence for both the "immigrant hypothesis" and the "endogenous hypothesis." Aspects of the application of genetics to human origin problems are also discussed. Lastly, dental and skeletal morphological characters are evaluated regarding their potential use as markers of population affinities.

Chapter 2 describes a biological approach to measuring migration. Facial morphology is emphasized as an important attribute in assessing population affinities. The appropriateness of the methods, the selected variables, and the population samples used in this study are also described and discussed.

In Chapter 3, principal components analysis is employed to reveal the pattern of facial variation and delineate the discriminating power of each variable. Path analysis (Li 1956) is applied to aid in clarifying the problem of Thai origins.

Chapter 4 discusses the results. It includes the interpretation

of the test results and a discussion of the implications of this research.

Chapter 5 summarizes the main points of this study and examines research implications for the study of other ethnic groups.

CHAPTER 1

THE MIGRATIONS OF THAI POPULATIONS

The origins and biological affinities of the modern Thai have been a source of continuing controversy for many years. Genetic, linguistic, archaeological and historical evidence has been used to address the problem. However, no firm consensus has yet been reached.

Although skeletal remains are the most direct evidence of population relations through time, the resolution provided by skeletal remains is not immediately apparent. For example, previous studies of skeletal remains have revealed both similarities and differences between the Thai and other ethnic groups. Previous studies on craniofacial metric traits have shown that modern Thai and Chinese fall in different clusters; the Thai are grouped with the populations now occupying the Southeast Asian mainland (Annam or Southern Vietnam, Cambodia, Laos, and Myanmar or Burma) and the Southeast Asian archipelago (Sumatra, Java, Bali, Borneo, Sulu, and the Philippines), while the Chinese are more similar to the modern

populations of Mongolia, Siberia (including the Buriat), Japan, Hong Kong, northern Vietnam, Guam, and Hawaii (Li, et al. 1991; Pietrusewski 1978).

Based on nonmetric data, Pietrusewski (1978) indicates that modern Thai and Chinese are members of a single large cluster distinct from Pacific Islanders and archaeological mainland Southeast Asians. This last group includes Metal Age crania from northeastern Thailand, dated from 3,600 B.C. to 300 B.C. (White 1986), which shows greater similarity to the indigenous populations of New Guinea and Fiji than to the modern Thai (Pietrusewski 1978). Li and colleagues (1991) found that the craniofacial metric pattern of prehistoric Thai males was distinct from the pattern shown by the modern Thai group, and that the prehistoric Thai are very similar to a Chinese Neolithic sample from Xian. On the other hand, a preliminary study of the human skeletal remains found at the Ban Kao Neolithic sites in Thailand, dated to 3,000 B.P., revealed that they are similar, metrically and nonmetrically, to present-day Thai (Sangvichien 1966a, 1966b). Sangvichien's account, however, is a descriptive one and is not based on statistical comparisons of the data.

The above-cited studies of the affinities of Southeast Asian populations reveal that they exhibit intergraded features that are

most likely the result of both migration and gene flow. Detailed population reconstructions are limited by the small samples available for early Holocene skeletal populations and by the incompleteness of comparable traits due to the fragmentary nature of skeletal remains. Further research using an expanded set of variables and extended sample sizes with new statistical approaches is needed in order to determine: (1) whether there are patterned craniofacial changes through time; (2) whether there is any craniofacial differentiation in different geographic regions of Asia; and (3) whether the populations separated by time and space can be differentiated by craniofacial traits.

Thai Migration Hypotheses

Scholars have studied the origins and migrations of the Thai for many decades (Borihantheptani 1968; Chit 1981, 1983; Dodd 1923; Prachakitkorachak 1919; Sangvichien 1966a, 1966b; Sood 1978; Srisak 1991, 1992; Suchit 1984, 1986, 1987a, 1987b, 1991; Tu and Chen 1978; Wales 1937, 1964). Most researchers base their inferences and conclusions on the analysis of historical documents; some scholars also use archaeological data to support their arguments. The two main models of Thai origins and migrations can be called the "immigrant hypothesis" and the "endogenous

hypothesis.”

The Immigrant Hypothesis

The immigrant hypothesis states that modern Thailand was populated by mass migrations from China during the second millennium A.D. Embedded in this general hypothesis are the notions that modern Thais are non-native to the area of modern Thailand, that they recently arrived in Thailand, and that they are not closely related to the region's archaeological populations. This hypothesis necessarily implies that Thailand's archaeological populations are not the ancestors of the modern Thai.

According to this hypothesis, China is usually postulated as the area from which the modern Thai migrated. The concept that the Thai originated in China was initially proposed by Western scholars. For example, Dodd (1923) proposed that the Thai originally came from China and moved southward through a series of seven mass migrations. Similarly, Wood (1959) stated that the thirteenth century conquest of China by the Mongolian leader, Qubilai (Kublai Khan) caused a massive southward movement of the Tai from Yunnan (Nanchao). In addition, Reischauer and Fairbanks (1960) also claim that the Chinese, at various times, forced Tai groups to migrate to the South. Borihantheptani (1968), a Thai historian, wrote a

history of Siam (in Thai) that is probably based heavily on the above sources. He described the Tai movement southward from the Altai mountains to the Huang He (Yellow River) (7,000 B.P.), then continuing south to the Changjiang He (Yangzi or Yangtze River) (4,500 B.P.) and later entering Thailand (A.D. 1,300). The belief that the Thai came from China has been integrated into all discussions of the history of Thailand as may be seen in a recent publication of the Tourism Authority of Thailand, a source of information with worldwide distribution:

The Thai people originated in southeastern China, in 650 AD, they founded the independent kingdom of Nanchao which thrived for 600 years. However, invasions and an unwillingness to be incorporated into mainstream Chinese society led to waves of migrations southward into what is now Thailand. Eventually several groups of Thai migrants united and established Sukhothai as their capital in the mid 13th century (Tourism Authority of Thailand 1991:46).

However, Chinese historians who disagree with the immigrant hypothesis have noted that there is no evidence to confirm any major population movement from China to Thailand during the early second millennium A.D. (Tu and Chen 1978).

The Endogenous Hypothesis

The endogenous hypothesis states that the modern Thai are

derived from indigenous groups. It includes both the argument that the modern Thai are similar to the prehistoric Thai and the proposition that there is a close relationship between modern Thai people and other modern and/or early Southeast Asians.

Supporters of this hypothesis do not accept proposed mass migrations of the Tai into "Siam" or modern Thailand. For example, Sangvichien (1966b) states that the patterns of craniofacial discrete traits displayed by the Ban Kao Neolithic skeletal population are similar to those of present day Thai people, with the exception that the archaeological population had a broader face than the modern Thai (Sangvichien 1966a). Furthermore, the craniofacial metric traits of modern Thais are more closely related to those of modern Southeast Asians than to modern and prehistoric East Asian populations (Li, et al. 1991; Pietrusewsky 1993, 1994; Pietrusewsky, et al. 1992).

Previous Studies of Thai Affinities

Cultural Evidence

Historical Evidence

Historically, China is well-known as one of the earliest centers for civilization and as a center of origin for so-called "Mongoloid" populations. Therefore, China is believed to be a

dispersal site for many ethnic groups, including Tai groups. However, it is still questioned whether the modern Thai (Siamese-Tai) are derived from Chinese populations. Borihanthepthani (1968) stated that the Tai migrated southward from the Altai Mountains in Mongolia to the Yellow and Yangtze rivers about 4,500 B.P. The Chinese subsequently forced many of the Tai to migrate further south (Reischauer and Fairbanks 1960), especially by the time of Qubilai's conquest in the early thirteenth century A.D. (Wood 1959). Moreover, Maurant (1983) concluded that the populations of East Asia and mainland Southeast Asia were restricted to north-south migrations because west to east movements were blocked by the major mountain ranges that run north-south. There is, however, no evidence to support such claims. In contrast, Thai historical literature, such as Tam Nan Sing Hon Na Wat and Pong Sa Wa Dan Lan Chang, indicate that Tai groups, living in dispersed regions of both South China and the Southeast Asian mainland between latitude 19° N to 26° N and longitude 95° E to 109° E, migrated to both the west and the east (cited in Srisak 1991 and Suchit 1991).

Several inscriptions and historical documents show that the Siamese-Tai lived in the area of the Thai Kingdom prior to the thirteenth century A.D. The name "Siamese" is the former name for the modern Thai. It first appears in the seventh-century Chenla

inscriptions, which are ancient Khmer inscriptions before the Na-Korn Luang (L'époque pre-Angkorienne) and Na-korn Thom periods (Chit 1981). This term also appears in an eleventh-century Cham inscription (Chit 1981; Majumdar 1985), a twelfth-century Vietnamese document (Chit 1981), a twelfth-century Khmer inscription under the Siam troop's Bas relief at Angkor Wat (Chit 1981), and a mid-thirteenth century Burmese inscription (Chit 1981). These inscriptions indicate a local presence for the Thai that predates the proposed 13th century arrival date.

Linguistic Evidence

Questions about Thai origins and migration patterns are also reflected in linguistic taxonomy as well. As mentioned earlier, the modern Thai population is understood to be any population within Thailand whose native language is of the Tai language family. Tai languages have at various times been categorized under the following language phyla: Austro-Asiatic, Sino-Tibetan, and Austro-Tai (Benedict 1942, 1975; Maspero 1912; Wulff 1934;). Thurgood (1985), and Edmondson and Solnit (1988) give brief reviews on the studies of Tai languages and their relationships by international linguists, i.e., Maspero (French), Wulff (German), Yakhontov (Soviet), and Benedict (American). Maspero (1912), for example, placed Tai

with Vietnamese (in the Austro-Asiatic group which now includes Mon-Khmer, Vietnamese, and related languages) because these languages contain glottalized consonants and back unrounded vowels as well as monosyllabicity and tone. Benedict (1975) later demonstrated that Austro-Asiatic and Austro-Tai are not closely related.

In addition, Sino-Tibetan and Austro-Tai groups are two well-known linguistic families into which the Tai languages have been placed. Tai languages, including the modern Thai (or Siamese), was placed with Chinese in the Sino-Tibetan language family by Wulff (1934). Wulff (1934) proposed that the Tai languages are related to Chinese languages on the basis of shared monosyllabicity and tonality. Yakhontov, however, stated that Tai and Chinese share little or none of the Swadesh common word list (as quoted in Edmondson and Solnit 1988:7).

Benedict's (1942) Austro-Tai group is the most plausible model of the relationships between Tai and other Asian languages. The Austro-Tai group includes four major branches, namely Tai-Kadai, Austronesian, Japanese, and Maio-Yao. These languages share many common cognates that demonstrate their historic and genetic relationships. These languages are characterized by "classifiers" (Jones 1970), a feature that distinguishes them from other Asian

languages. Benedict (1975) not only differentiates Thai and Chinese languages, he also postulates the direction of cultural influence from Southeast Asia to China. This suggestion is based on his inference that some Chinese words are loan words from Austro-Tai.

The Austro-Tai hypothesis is widely accepted by most linguists working in the area today (Edmondson and Solnit 1988; Reid 1988; Thurgood 1985). Recently, an analysis of human dental remains (Turner 1989), to be discussed in a later section, has also lent support to this hypothesis. Figure 1 charts the linguistic relationship of the Tai languages, as proposed by Benedict.

The wide distribution of Tai languages in South China and mainland Southeast Asia does not necessarily imply that there were major population movements of the Thai from China. If there had been mass movement of the Thai, there should be some remnant of Tai languages or words in northern regions such as the Altai mountains. The distribution of Tai languages may be due to political dominance of the Tai, language being a form of assimilation of neighboring groups (Chit 1981; Condominas 1990). Nevertheless, the possibility that the wide distribution of the Tai languages may be due to colonization rather than trade alone leads to a consideration of the identity of the Austro-Tai homeland.

Prior to considering the Austro-Tai homeland, the position of

Austronesian, a descendant of Austro-Tai, is important to review as it has been studied intensively, both linguistically and archaeologically. Dyen (1962a, 1962b) first proposed New Guinea (Melanesia), and later Formosa (or Taiwan) as candidates for the Austronesian homeland (Dyen 1963). Others also support an origin on Formosa (Blust 1988; Dahl 1976). Linguistic reconstruction proposing Taiwan as the homeland for Proto-Austronesian prior to dispersal in the Pacific fits very well with the archaeological evidence. The Taiwanese archaeological evidence reveals that there were indigenous people in Taiwan from 5,000 B.C. to 3,000 B.C. (Chang 1973). Their cultural remains are characterized by flake tools and plain cordwares. There was then an apparent break of about 500 years in the occupation of Taiwan. From 2,500 B.C. to 500 B.C., Yuan-shan pottery, characterized by round bodied, loop-handled, and ring-pedestaled vessels, spread across the northern region of Taiwan. Southwestern Taiwan was occupied by the Taiwan-Lungshanoid group between 2,000 B.C. and 500 B.C. Among the distinctive characteristics of the Taiwan-Lungshanoid group are tripod pottery and the checked-press design (Chang 1971). Based on the analyses of archaeological ceramics, Chang and Stuver (1966) infer that the Taiwan-Lungshanoid people were in contact with the Yuan-shan people of Northern Taiwan by about 500 B.C.

The Austronesian group has also been viewed as the earliest cultivator of rice. However, the question of rice domestication in Taiwan is controversial. The study of botanical remains from Jih-Yeuh Tan (Sun Moon Lake) revealed that the frequency of *Chenopodium* pollen dramatically increased about 2,200 B.C. (Tsukada 1966, 1967). This is interpreted as evidence that the area was cleared for cultivation (Chang and Stuiver 1966; Tsukada 1966). If true, then plant cultivation began in Taiwan at approximately 2,200 B.C. This issue is, as yet, unresolved due to questions raised by Flenley (1985) and Golson (1985) concerning the accuracy of the dates.

These archaeological data have been used to support the linguistic data in suggesting that there were at least two Austronesian languages in Taiwan: Atayalic and Tsouic. These two groups are thought to represent both the Yuan-shan and Taiwan-Lungshanoid archaeological cultures (Chang and Stuiver 1966). A simple reconstruction, however, of a one-to-one correspondence, between the linguistic groups and archaeological groups cannot be maintained with the present data. Both groups are thought to have crossed to Taiwan from the Asian mainland (Dahl 1976).

Given that Austronesian, a descendant language group, originated on Taiwan, the proto-Austronesian or Austronesian

ancestral language, namely Austro-Tai, must have originated somewhere on the Asian mainland prior to the movement of people to Taiwan. South China and mainland Southeast Asia are the two possible Austro-Tai homelands. South China is a possibility because it shows the greatest linguistic diversity of Kadai languages and therefore it could be the Kadai homeland (Edmondson and Solnit 1988). However, it should be noted that the most diverse area is not inevitably the original place of linguistic dispersal (Lehman 1963). Tai speakers also are spread throughout mainland Southeast Asia, especially Burma, Thailand, Laos, and Vietnam. A Thai historical account, Tam Nan Sing Hon Na Wat, indicates that “Tai Muang” speakers have lived around the Kok River, north of Thailand, since the beginning of the Buddhist Era (about 2,500 years ago) (cited in Chit 1981).

In sum, according to linguistic accounts, Tai languages are placed within the Austro-Tai language family and are separated from the Chinese language, which is grouped in the Sino-Tibetan family. As to the homeland for these Austro-Tai speakers, there are two distinct possibilities: South China or Southeast Asia. The following section on archaeological evidence from Thailand provides additional information with which to address the origin of Austro-Tai.

Archaeological Evidence

The archaeological evidence in mainland Southeast Asia shows gradual cultural change; there are no signs of any visible cultural breaks or archaeological site unit intrusions. Archaeological excavations in Thailand reveal that humans continuously occupied the area for many millennia. The time period in Thailand between 3,600 B.C. and A.D. 300 has been especially well-documented, and that is the material that will be discussed here. The cultural remains of selected sites in Thailand are summarized in Table 1 and their locations are given in Figure 2.

Pleistocene Epoch

The earliest known sites are found in northern Thailand (Pope 1985; Sorensen 1985). At Ban Mae Tha in Lampang province, core stone tools were discovered under a basalt layer that was dated to $800,000 \pm 300,000$ and $600,000 \pm 200,000$ years ago by the potassium-argon (K/Ar) and paleomagnetic methods, respectively (Pope, et al. 1986).

In southern Thailand, the earliest known sites are located in Krabi province (Anderson 1987; Pookajorn, et al. 1991). The lowest level of Lang Rongrien Cave is dated to as early as 37,000–27,000 years ago (Anderson 1988). A number of flake tools found at the site

are said to be similar to those found at Tabon Cave in the Philippines, Niah cave in Sarawak, and the Nguom and Mieng Ho sites in Vietnam (Anderson 1988). Not far from the Lang Rongrien site, human skeletons were found at the Moh-Khiew cave site (Pookajorn, et al. 1991). The one skeleton found in the lowest level at Moh-Khiew is dated to 26,400–25,200 B.P. (Pookajorn 1994).

In addition, another site in central Thailand has recently been dated to 15,000 B.P. (Rasmi Shoocongdej, e-mail to the author 1994). This preliminary (uncalibrated) date is taken from charcoal samples from a hearth at Lang Kamnan Cave site in Kanchanaburi province. The above-cited archaeological sites are given here as a general indication of the extent of human occupation in Thailand long before the Holocene Epoch.

Holocene Epoch

Gorman (1969) found many cave sites in the North of Thailand, including Spirit Cave (9,000 B.C.–5,500 B.C.), Pah Chan Cave (5,500 B.C.–3,600 B.C.), and Banyan Valley Cave (3,600 B.C.–A.D.700). Potsherds from Spirit Cave date to 6,000 B.C., which is an early date for pottery in this region. The assemblages contain more core tools than flake tools, but flake stone tools shaped like those used to harvest rice are also present (but see Srisak 1988 for other

functional interpretation of tool use). These sites are near T.T. Chang's (1976b) proposed zone for the origins of wild rice between Latitudes 20–23° N. Some scholars even call this group of people “Neolithic rice cultivation Austronesian” (Glover 1979). However, the remains of rice found at Banyan Valley Cave were erroneously reported. Chang (1976a) reports that the Banyan rice remains are wild rice, while Yen (1977) believes they are domesticated rice. The rice husks reported by Glover (1985) are dated to 1,000 B.C. and A.D. 1,000, but dates between 3,500 and 3,000 B.C. are noted by Amphan (1985) and Solheim (1971).

At many prehistoric sites in the Sakonnakorn and Korat basins of northeastern Thailand, many human burials (total minimum number of 390 individuals) have been excavated as well as a number of potsherds, metal artifacts, and rice husks (Higham & Kijngam 1984). The earliest occupational stratum in this region is dated to at least 3,600 B.C. (White 1986). It has yet to be determined if these people came into the region from northern Thailand (Gorman 1971) or from the East, specifically Laos and Vietnam (Srisak 1992). However, the development of metallurgy in Ban Chiang and the nearby sites shows that they knew how to smelt and cast artifacts. Further, there are many metal sources on the Southeast Asian mainland. Smiths in the Ban Chiang region used tin-bronze alloys,

the bi-halved mould, and cast their metals by lost wax techniques (Pisit 1987). Clay crucibles, sandstone moulds, and metal ingots survive as evidence of metallurgy at these sites. The local development of metal working can be detected in the artifacts themselves. Early in the sequence, smiths used 3% tin bronze and worked their metal by the cold hammered annealing process. Later, they used 20% tin bronze in a hot-working technique (Pisit 1987).

Their knowledge of heat treatment or pyrotechnology may have come from pottery making, which was known before metal working. The oldest pottery at Ban Chiang dates to between 3,600 B.C. and 2,500 B.C.; bronze is not present in the sequence until around 2,000 B.C. (White 1986). Metallurgy probably developed first in Northeast Thailand, where the earliest furnaces (Higham 1988) as well as the ore sources were discovered (Natapintu 1988; Pigott 1985).

Metallurgy in Thailand appears to be an independent invention. Although Chinese bronze also dates to 2,000 B.C. (Meacham 1983), the Chinese bronze working techniques were different from those of early Thailand. Also, the earliest North Vietnamese bronze artifacts (containing high lead content which allows a low firing temperature) are dated to only 1,000 B.C. (Davidson 1979). Most bronze artifacts found in the Southeast Asian islands are more recent than the ones found in Ban Chiang, Non Nok Tha, and Ban Na Di, Thailand. The use of

iron in Thailand, which is dated back to 500 B.C. or earlier (White 1986), also suggests local development as the archaeological evidence from these sites reveals simultaneous use of bronze and iron (Pisit 1987). Local smelting is evidenced by the presence of iron slag (Bayard 1992). Further, Bronson (1985) argues for the development of iron production in Thailand as opposed to a Chinese origin based on different technologies.

Higham and Kijngam's (1985) analysis of floral and faunal remains suggests that the environment of these sites in Thailand was suitable for rice growing, probably by the broadcasting technique. Their inference is supported by the presence of rice chaff in pottery temper, the frequency of which increases through time. Evidence of animal domestication was also discovered, and the bones of cattle, pigs, dogs, and chickens are found in association with human burials. The bones of water buffalo are used as indirect evidence for rice growing. This is based on exostosis of the third phalanx, which is thought to be evidence that water buffalo were used as draft animals (Higham & Kijngam 1985).

Where did the early Ban Chiang people go? From historical sources we know that the Ban Chiang region was unoccupied from A.D. 300–A.D. 1800 after which the Tai Puan moved in from Laos (Suthiragsa 1979). The earlier group may have moved away because

of a natural disaster such as flooding, which has been recorded in Tamnan Urang Ga Tat (cited in Suchit 1987a). However, Metal-Age descendants of early communities in Thailand may have remained in Thailand, but in small, dispersed groups. Suthiragsa (1987) supports this interpretation of cultural continuity based on the spiral decoration on pottery found in Thailand from the Late Ban Chiang period through the Dvaravadi period (A.D. 600–A.D. 1300).

South of the Ban Chiang region, petty states developed during the Late Iron Age in the Korat basin (Srisak 1988). Iron and salt were important trade goods for these early states (Solheim and Ayres 1979; Srisak 1992). Fortified mounds found in the northeast region are thought to indicate complex political organization and warfare (Smith 1979; Srisak 1988). These petty states were the forerunners of later states in northeast and central Thailand. They display local continuity through the 14th century A.D. even though the influence of the Khmer is demonstrated in the art styles of many archaeological monuments.

Excavations at the coastal site of Kok Panom Di also confirms that metal smiths were not confined to northeastern Thailand. The burials and grave goods at Kok Panom Di, which are dated between 2,000–1,400 B.C., also reflect the presence of social rank and social complexity (Higham 1989).

In sum, cultural evidence of plant domestication and metallurgy indicate that Thailand may represent an independent center of cultural innovation, rather than a mere recipient of technological advances from China. The archaeological evidence reveals local cultural continuity in Thailand from the middle of the Holocene to the beginning of the proto-historical period. This continuity is also confirmed by the intensive cultural remains found throughout the area, especially between 5,000 B.C. and 500 B.C. (Higham 1989). Although human skeletal remains from earlier than 5,000 B.P. are rare, a recent excavation at Krabi, southern Thailand, produced one human skeleton that dates to 25,000 B.P. (Pookajorn 1994). In short, mainland Southeast Asia, as suggested by the archaeological remains, is an ancient center of occupation where the Austro-Tai homeland can be placed.

Nevertheless, the question of where the modern Thais came from is not yet settled. Based on archaeological evidence in mainland Southeast Asia, especially the site at Khok Phanom Di (Thailand), Higham (1989) proposes that incipient agricultural activities were practised in Thailand as early as 5,000 B.C. This implies that the method of rice cultivation may not have been brought in by the Austronesian group from South China. Bellwood (1992), although he disagrees with the interpretation of vast

population migrations from South China to mainland Southeast Asia, proposes that early groups came from South China about 5,000 B.C. and gradually replaced the indigenous Austro-Melanesian populations (Bellwood 1992).

Genetic Evidence

The heterogeneous ethnicity and genetic make-up of the Thai make it difficult to determine their origins and affinities. Many genetic studies of Southeast Asians, including the Thai, have been published (Flatz 1967; Flatz and Sringam 1964; Kirk and Lai 1961; Lie-Injo 1976; Phansomboon, et al. 1949; Poolsuwan 1991; Sanpitak, et al. 1972; Tuchinda, et al. 1968). It has been found that blood groups are poor instruments for determining relationships between populations. The ABO, and other blood group systems may aid in ruling out relationships between populations but they cannot be used to demonstrate relationships. Simmons (1976), for example, rules out close relatedness between populations in Southern China and Thailand based on the presence or absence of rh blood group antigens, even though the two groups match for 19 other blood group antigens. In other words, blood group genes can be applied to interpret recent relationships between populations, but not to solve the problem of biological origins (Simmons 1976). However, studies

of genetic trait distributions in various regions of the world led to the interesting discovery of Gamma-immunoglobulin polymorphisms as genetic markers (Grubb 1970; Steinberg 1969; Vos, et al. 1963). The frequencies of immunoglobulin Gm have been used as genetic indicators because many haplotypes have limited distributions.

It has been reported that Southeast Asians possess higher frequencies of Immunoglobulin Gm^{fa;b} whereas Chinese populations have high frequencies of Gm^{za;bst} (Schanfield 1980). However, Schanfield and Gershowitz (1973) view these differences as a cline-like gradual change in the frequency of the Gm haplotypes from north to south. These traits may or may not be under selective pressure. Kelly (1990) concludes that the “haplotype” distribution is more likely ascribed to a common origin, in general, and the “allele” distribution reflects natural selection. There is no clear consensus on this subject as yet.

In addition to the Gm factor, hemoglobin E (Hb-E) has been used to characterize population differences in Asia. Because Hb-E appears to be maintained at relatively high frequencies in malarial environments of Southeast Asia, it has been suggested (Kirk 1986; Poolsuwan 1991) that malaria is a primary selective factor acting on Hb-E frequency. The alteration in Hb-E frequency is presumed to have been established in the early or middle Holocene (Poolsuwan

1991). The adaptive advantage afforded by Hb-E in resistance to malaria is debated (Poolsuwan 1991), and in any case, Hb-E homozygotes are under no selective disadvantage. This feature allows anthropologist to use Hb-E, even though it may not be a neutral allele, as a genetic marker with which population relationships can be reconstructed. Genetic studies of modern Asian populations indicate that a high frequency of Hb-E is common for the indigenous populations of Southeast Asia (Livingstone 1967; Wasi 1983), and rare among Chinese (Mourant 1983). Central Thai have average Hb-E levels of approximately 13% with levels in northeastern Thailand being as high as 30-40% (Na-Nakorn, et al. 1956; Wasi, et al. 1967), while expatriate Chinese living in Thailand exhibit an Hb-E frequency of less than 0.1%. If the Thai are supposed to be derived from Chinese populations, how can this difference be explained? The difference appears to suggest that the populations are not genetically closely related.

Poolsuwan's (1991) study on allele frequency distribution of Glucose-6-phosphate dehydrogenase (G-6PD) deficiency, hemoglobin-E (Hb-E), and Beta-thalassemia (B-thal) in association with malarial endemicity indicates that modern Thais exhibit closer genetic affinity with Austroasiatic Khmer than with Chinese migrants. Similarly, comparison of genetic trees and linguistic

phyla by Cavalli-Sforza and colleagues (1988) suggested a closer genetic relationship between Thai and Mon-Khmer than between Thai and Chinese. Mon is another ethnic group in Thailand whose native language is Mon, an Austroasiatic language (Diffloth 1984). Mon is also found elsewhere in Southeast Asia, e.g., Burma and Cambodia.

Conversely, a dermatoglyphic study of contemporaneous populations (Sirijaraya 1988) shows that Thais in Bangkok are more closely related to Chinese than to Mon. However, this dermatoglyphic study may be a reflection of the historical increase in admixture between modern Thai and Chinese (living in Bangkok, Thailand) in comparison with modern Thai and Mon.

Dental and Skeletal Evidence

Biochemical tissues yield genetic data that may be used to determine the biological distance between populations of living human groups. Among archaeological populations, teeth and bones are the only available hard evidence that records genetic information. Dental and skeletal morphologies are the only variables available to assess biological similarities among populations that can be compared across time.

Using both linguistic and archaeological evidence, Turner (1989) differentiates Thai dental characteristics from those of the

Chinese and refers to them as Sundadont and Sinodont, respectively. Turner (1989) proposes that Sundadonts (Southeast Asians) are characterized by low frequencies of shovel shaped incisors, low frequencies of three-root lower first molars, and high frequencies of four-cusped lower second molars. He also states that the Sundadont populations gave rise to Sinodont populations who exhibit more specialized characteristics. The Sundadont group is composed of mainland Southeast Asians, including some Southeast Asian islanders as well as the Minogawa population in Japan (17,000 B.P.). The Sinodont group is composed of mainly Chinese, American Indians, modern Koreans, and modern Japanese.

There are many studies of Southeast Asian population affinities using skeletal morphologies of archaeological or recent populations, or both (Brace 1978; Brace, et al. 1991, n.d.; Li, et al. 1991; Pietrusewsky 1978, 1981, 1993, 1994; Pietrusewsky, et al. 1992). Earlier studies of Thai crania and comparative studies on the crania of Thai and ethnic Chinese who live in Thailand are, in general, preliminary and descriptive (Sanchai 1971; Tien 1951). Previous comparative studies on Southeast Asian skeletal populations provide evidence of the relatedness of these groups, but they offer no indication of ancestral-descendant relationships among them.

Conclusion

Previous studies on the origin and migration of Thai populations have used genetic, linguistic, historical, and archaeological evidence. These studies can be summarized by two main hypotheses: the “immigrant hypothesis” and the “endogenous hypothesis.” The former proposes mass population migration from China into Thailand, the latter proposes indigenous population development. Historic Thai literature disagrees with the limitation on population migration in only the north-south direction proposed by Maurant (1983). Linguistic taxonomy of Thai and Chinese indicates that Thai and Chinese are very remotely related languages. Abundant archaeological materials unearthed in Thailand reveal that the area was continuously occupied since the beginning of the Holocene with gradual cultural change. Also, the majority of recent genetic studies point to a close genetic affinity between Thai and other indigenous ethnic groups such as Austroasiatic Khmer than between Thai and Chinese (but see Sirijaraya 1988). Dental evidence also indicates separation between East Asians (e.g., Chinese) and Southeast Asians (e.g., Thai). Current interpretations of dental evidence are consonant with an early migration from Southeast Asia into China. Although the similarities and differences among Southeast Asians, including the Thai, have been demonstrated by

other researchers, no attempt has been made to find the ancestral population(s) of the modern Thai.

The present study focuses on the origins and biological affinities of the modern Thai. This research aims to investigate the biological relationships between modern and archaeological populations using craniofacial metric and discrete traits. The biological approach, emphasizing facial morphology, to measuring migration will be discussed in the next chapter.

Table 1

The Archaeological Evidence from the Selected Sites in Thailand

Age	Location	Cultural Remains	Sources
A.D. 1,400	North & Central	Stone inscriptions	(5)
A.D. 600–700	Northeast & Central	Iron, Salt, Fortified mound	(8); (9)
2,000–1,400 B.C.	Kok Panom Di	Grave goods, Rice	(4)
3,600 B.C.–A.D. 300	Ban Chiang	Pottery, Rice,	(3); (11)
	Non Nok Tha	Copper base matalurgy	(2)
	Ban Na Di		(4)
6,290–5,705 B.C.	Ban Chiang	Hearth (?)	(1 1)
3,600 B.C.–A.D. 700	Banyan Cave	Rice husks	(3)
5,500–3,600 B.C.	Pah Chan Cave	Pottery	(3)
9,000–5,500 B.C.	Spirit Cave	Core stone tools	(3)
0.03–0.04 mya	Lang Rongrien Cave	Flake stone tools	(1)
	Moh-Khiew Cave		(6)
0.8±0.3/0.6±0.2 mya	Mae Tha	Core stone tools	(7); (10)

Sources: (1)Anderson (1987); (2)Bayard (1979); (3)Gorman (1969); (4)Higham (1989); (5)Chit (1981); (6)Pookajorn, et al. (1991); (7)Pope, et al. (1986); (8)Smith (1979); (9)Solheim & Ayres (1979); (10)Sorensen (1985); (11)White (1986).

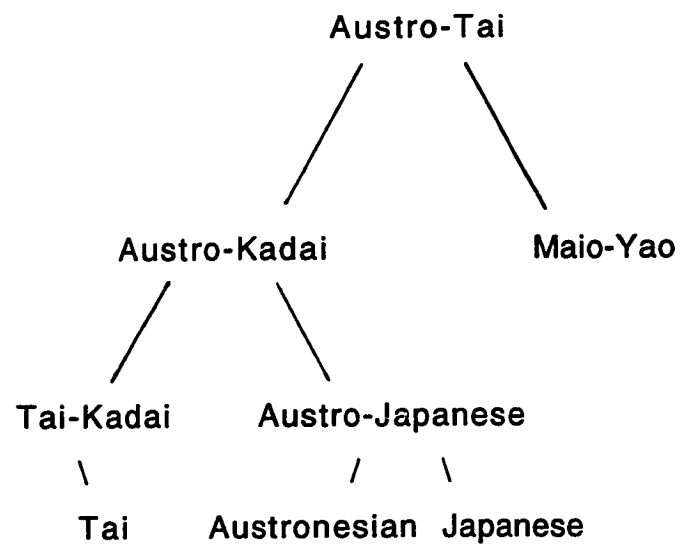


Figure 1. The Austro-Tai Language Family-Tree (Adapted from Thurgood [1985])

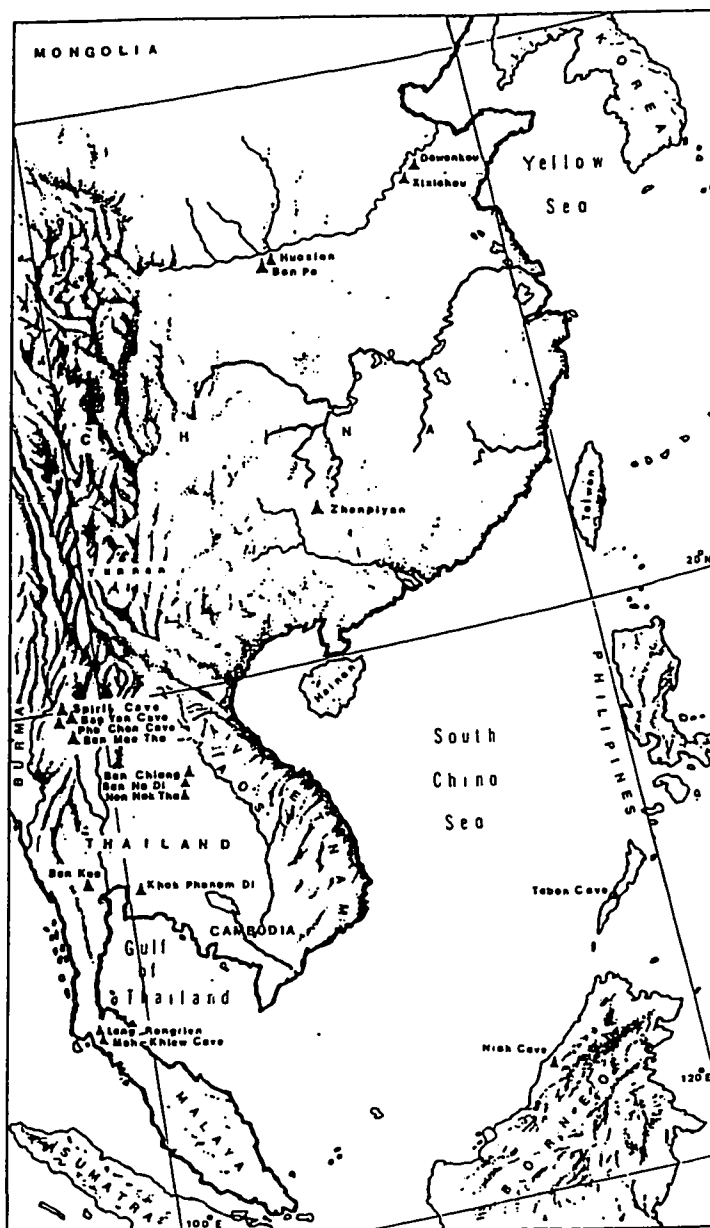


Figure 2. Selected Archaeological Sites in Thailand and China

CHAPTER 2

A BIOLOGICAL APPROACH TO MEASURING MIGRATIONS AND DESCENT

There has been great interest during the last three decades in reconstructing biological distance between or among past and/or modern human populations. This chapter presents a brief overview of earlier research concerning the measurement of biological distance among populations. The proposed method for solving the problems posed by a biological approach to measuring population migrations is also discussed.

Measures of Biological Distance

Biological distance is a measure of biological relatedness between or among different populations using genotypic and/or phenotypic traits as evidence of relatedness. The variation in living populations can be measured using genetic factors. However, the biological differences between past and present populations are more appropriately measured using morphological features since the available evidence from past populations is primarily restricted to skeletal material. Moreover, Sanghvi (1953) used both serological

and skeletal morphological traits to measure biological distance and concluded that they were equivalent. Therefore, this study uses a morphological approach to measure biological distance since it deals with both past and present populations of Thai and Chinese people.

Morphological Approach

Morphological variation can be categorized into metric traits and nonmetric traits. Metric traits, or anthropometric traits, are features that vary incrementally, and can be measured using the osteometric board, sliding calipers and spreading calipers. Nonmetric traits are also known as anthroposcopic traits, discrete traits, discontinuous features, or epigenetic variants; they are further divided into hypostotic and hyperstotic traits. A hypostotic trait is formed by a lack of bone growth, which leaves gaps or spaces between bones, such as skeletal foramina. The appearance, position, and shape of the skeletal foramina are considered discrete traits. Additionally, numerous sutural features, such as an increased number of sutures on the skull, are considered hypostotic traits. A hyperstotic trait refers to a condition of excessive bone growth such as auditory exostoses (Sjovold 1973).

Metric Traits Versus Nonmetric Traits

The determination of human population affinities based on

skeletal remains has been attempted by many researchers (Angel and Kelly 1990; Ayers, et al. 1990; Baker, et al. 1990; Brace, et al. 1991; Brooks, et al. 1990; Brues 1990; Curran 1990; Fisher and Gill 1990; Gilbert and Gill 1990; Gill and Gilbert 1990; Hinkes 1990; Howells 1973, 1989; Iscan 1990; Iscan and Cotton 1990; Ishida and Dodo 1992; Kellock and Parsons 1970; Napoli and Birkby 1990; Pietrusewsky, et al. 1992; Rhine 1990). These researchers often disagree over the relative accuracy of results obtained by use of nonmetric versus metric traits in deriving measurements of biological distance, or racial affiliation (Anderson 1968; Berry 1968; Birkby 1973; Corruccini 1974, 1976; Finnegan and Coopridge 1978; Finnegan and McGuire 1979; Gaherty 1973; Molto 1979; Ossenberr 1976; Saunders 1989; Sjøvold 1977; Stevens 1983; Zegura 1973).

For example, Wilkinson (1970) studied Native American skeletal morphology and concluded that metric traits give more stable results than discrete traits when dealing with variability and small sample size. Conversely, it has been argued that discrete traits are more accurate because they lack sexual dimorphism, they are age independent, and there is no correlation between variables. It has been argued that little or no correlation between variables results in stronger measurements of biological distance (see

Corrucini 1974 for discussion). Corrucini (1974) used a human skeletal collection to test the above assumptions. The results were that sexual dimorphism is statistically significant in discrete traits, although less significant than metric traits; that age affects discrete traits more than metric traits; and that the correlations between variables in discrete and metric traits are equal. Thus, it is not accurate to argue that discrete traits are more useful than metric traits.

Furthermore, many nonmetric traits such as fossae and tori show continual growth, that may result in differences in the observed expression or level of development for the trait. These traits must, however, be scored by the researcher. This is problematic because different observers produce different scoring, which results in high levels of inter-observer error. Also, both nonmetric and metric traits are affected by bone growth and bone resorption, therefore they should not be scored or measured for very young or very old individuals. Comparison should be made only on those who have reached adulthood, otherwise the epiphyses are not yet closed and the bones are still growing. As for sexual dimorphism, females are normally smaller than males resulting in metric trait variation based on size. The same is also true of some discrete traits such as hyperforation in the distal humerus, which is

more common in females.

In short, human trait expression is mitigated by many factors. It cannot yet be concluded that metric traits are better biological distance measures than nonmetric traits, or vice versa. Although Sanghvi (1953) reported that metric traits gave similar estimates of biological distance as genetic serological factors, nonmetric traits were not part of that research. Discrete traits, however, are claimed to be better characteristics for differentiating close populations among some American Indians (Saunders 1978). Discrete traits may also be useful with archaeological populations that are normally fragmentary or incomplete, and in which metric traits cannot be measured. Therefore, both metric and nonmetric traits are examined in the present study.

Facial Morphology Versus Cranial Morphology

Although many researchers agree that the cranium, especially the facial portion, is the best racial indicator among skeletal populations, there is no firm consensus as to which facial variables are the most useful indicators of population affinities or whether the same traits are useful for all population comparisons (Birkby 1973; Brooks, et al. 1990; Brothwell 1959; Brues 1990; Curran 1990; Gill 1984, 1986; Gill and Gilbert 1990; Gill, et al. 1988; Howells

1989; Hughes 1967; Hughes 1980; Ishida 1992; Pietrusewsky 1981; Pope 1991; Rhine 1990).

Facial morphology has been accepted as an important set of variables for assessing Asian affinities (Hughes 1967). Facial features have a genetic basis and are “less prone to developmental disturbances” (Hershkovitz, et al. 1990:318). They can be used to trace biological relationships between populations. It has been argued that facial traits display a greater genetic component than traits of the vault or base of the skull (Hershkovitz, et al. 1990). For this reason and due to the relative abundance of facial landmarks in comparison to traits of the cranial vault and base, facial features are used more often than cranial features in this study. In addition, living populations of Asia exhibit a short mid face (Enlow 1975), and a high and wide zygoma (Howells 1983; Wolpoff, et al. 1984). Because of the distinctiveness of the Asian cheek morphology, many measurements are taken in the area of the zygomatic bone.

Selected Craniofacial Traits

The morphological traits used in this study can be divided into two categories: craniofacial metric traits and craniofacial discrete traits. The craniofacial measurements include maximum cranial length, maximum cranial breadth, mid (or upper) facial height,

bizygomatic breadth (or maximum facial breadth), biorbital breadth, orbital breadth, orbital height, nasal breadth, nasal height, interorbital breadth, (lower) facial breadth (or maximum width of maxilla bone), and three malar bone measurements (frontomale orbitale to superior zygomaxillare, frontomale orbitale to inferior zygomaxillare, and superior zygomaxillare to inferior zygomaxillare). These craniofacial variables were measured using sliding and spreading calipers (The illustrations and descriptions of these measurements are provided in Appendix I with reference to Black [1928], Martin [1928], and Morant [1923]).

The cheekbone has not been used extensively in previous research on facial measurement analyses even though this bone is not fragile, and it forms an important component of the broad face which is characteristic of Asian populations. Unfortunately, the three malar bone measurements are not provided in the published data of the archaeological Chinese group. These published data have been derived from Wu and Zhang's work (1985). Therefore, these three zygoma measurements will be omitted in comparisons involving the archaeological Chinese groups.

Eight of the fourteen selected metric traits used in this study (maximum cranial length, maximum cranial breadth, facial height, bizygomatic breadth, orbital breadth, orbital height, nasal breadth,

and nasal height) have been shown to convey meaningful variation in phylogenetic studies (Giles 1976). These same craniofacial traits have been shown to correlate with geographic variation among closely related populations (Hanihara 1985a, 1985b).

Nonmetric traits include metopic suture, infraorbital suture, nasofrontal suture, os japonica, supraorbital foramen, infraorbital foramen, zygomaticofacial foramen, parietal foramen, subnasal character, incisura malaris, shovel-shaped upper first incisor, four-cusped second lower molar, and rocker jaw (see illustrations and descriptions of the traits in Appendix I). These traits are known to be useful for inter-population comparisons (Pietrusewsky 1978; Pope 1991; Turner 1989).

Population Samples

The investigation of the biological relationships between Thai and Chinese populations, as well as between prehistoric Thai and Chinese populations, is based on both data collected by myself and published data for the prehistoric Chinese sample. The sample frame for this project is primarily based on prehistoric populations found in archaeological sites in Thailand and at Neolithic sites in China; the modern skeletal populations are those from medical schools and museums.

The data used in this study are all from adult individuals. They consist of 307 cases which can be divided into 4 subgroups as shown in Table 2. The samples include 125 modern Thai, 70 modern Chinese, 46 prehistoric Thai, and 66 prehistoric Chinese individuals. The archaeological Thai data are from Ban Na Di, Ban Kao, Tam Ong Ba, Kok Panom Di, and Non Nok Tha. Data for the Neolithic Chinese skulls were gleaned from published accounts. These Neolithic Chinese data are from various archaeological sites, including Banpo (Yan, et al. 1960a, 1960b), Huaxian (Yan 1962), Dawenkou (Yan 1972), Xixiahou (Yan 1973), and Zhenpiyan (Zhang, et al. 1977).

Measuring Migrations and Descent

The craniofacial variables described above will be analyzed by applying a multivariate technique for inter-population comparisons of biological distance. A result indicating close biological distance between archaeological and modern Thai, for example, will indicate early migration; whereas a result indicating close biological distance between the modern populations would reflect recent migration. Principal components analysis is employed to determine the best associated morphological traits for population separation. This method of analysis may also provide a view of the patterns of facial variation among different populations. Subsequently, path

analysis (Li 1956; Wright 1934) is applied to the same data set in order to test for the most highly correlated groups to determine ancestral-descendant relationships. All the analyses are performed using SYSTAT (Wilkinson 1989) software. Frequencies of discrete traits will also be compared among these populations.

Principal Components Analysis

Principal components analysis was developed by Pearson (1901), and Hotelling (1933). It has been extensively used for research in psychology and education (Jackson 1991). Recently, principal components analysis has been used by anthropologists interested in morphology and biological affinity among different populations (Chen 1989; Hanihara 1985a; Hanihara 1993; Lukacs and Hemphill 1993). The usefulness of principal components analysis lies in its ability to summarize a set of variables into a few components. An important aspect of a component is that it represents a "line of closest fit to a system of points in space" (Pearson 1901). In other words, principal components analysis determines the best associations between variables. The variables in high loading coefficients, which are obtained through this technique, are interpreted to explain patterns of variation. In sum, principal components analysis can be applied to simplify the

investigation of multivariate data. In the present study, this technique is applied to test the hypothesis that there is no significant between-group difference in craniofacial morphology.

Path Coefficients

The path coefficient method was first introduced by Wright (1934). Its impact on population genetics has been elaborated by Li (1956). It is accepted that metric traits are expressions of genetic traits that are controlled by a certain number of genes (Li 1956). The principle of path coefficient analysis is that “the correlation between two variables [*groups*] is the sum of all the paths connecting them” (Li 1956:199, emphasis added). Mizoguchi (1986) demonstrated the usefulness of path analysis to assess the degree of genetic information contributed from parental groups to descendant groups and to detect the presence of unknown factors (ancestors) in his investigation of Japanese origins based on cranial measurements.

Path analysis is applied to Q-mode correlation coefficients in order to determine the relationships between populations. Therefore, craniofacial metric traits drawn from the above-mentioned samples will be analyzed using path coefficients in order to determine genetic correlations, as well as genetic components

between ancestral and descendant groups. Figure 3 illustrates the proposed path relationships for Thai origins.

Again, the working hypothesis is that: "The higher the degree of genetic correlation between two populations, the closer the biological distance." I hypothesize that modern Thai are more closely related to archaeological Thai than to any modern or archaeological Chinese groups. In other words, I am testing the endogenous hypothesis described in Chapter 1.

Conclusion

This study adopts a morphological approach as an appropriate biological method for measuring the migrations of the modern Thai. Craniofacial metric and nonmetric traits included in this study are selected because of their high genetic component. Population samples of past and present Thai as well as Chinese populations are also described. These data will be analyzed to reveal the degree of biological distance among the populations under study. The statistical analyses are the subject of Chapter 3.

Table 2

Thai and Chinese Skeletal Population Samples

Population	No. of Female	No. of Male	No. of Unknown Sex	Total	Sources
<i>Modern</i>					
Thai	5	10	0	15	AMNH
	24	28	0	52	Siriraj Hospital
	<u>8</u>	<u>34</u>	<u>16</u>	<u>58</u>	Suan Dok Hospital
Total	37	72	16	<u>125</u>	
Chinese	5	12	0	17	Siriraj Hospital
	1	4	0	5	Field Museum
	<u>14</u>	<u>34</u>	<u>0</u>	<u>48</u>	AMNH
Total	20	50	0	<u>70</u>	
<i>Prehistoric</i>					
Thai	8	11	1	20	Siriraj Hospital
	<u>9</u>	<u>17</u>	<u>0</u>	<u>26</u>	UNLV
Total	17	28	1	<u>46</u>	
Chinese (N.)	21	36	0	57	(1); (2); (3); (4)
Chinese (S.)	<u>4</u>	<u>5</u>	<u>0</u>	<u>9</u>	(5)
Total	25	41	0	<u>66</u>	

Note: AMNH is abbreviated from American Museum of Natural History, New York, USA. Siriraj Hospital is located in Bangkok, Thailand. Suan Dok Hospital is located in Chiang Mai, Thailand. Field Museum of Natural History is located in Chicago, Illinois, USA. UNLV is abbreviated from University of Nevada, Las Vegas, USA.

Sources: (1)Yan, et al. 1960a, 1960b; (2)Yan 1962; (3)Yan 1972; (4)Yan 1973; and (5)Zhang, et al. 1977.

Here, X1 denotes Neolithic Chinese groups;

X2 denotes archaeological Thai groups;

Y1 denotes modern Chinese;

Y2 denotes modern Thai;

U1 denotes a disturbance factor or unknown ancestor for Y1;

U2 denotes a disturbance factor or unknown ancestor for Y2.

The straight lines show correlation coefficients between two variables or two population groups. The curved line shows the joint effect of exogenous variables.

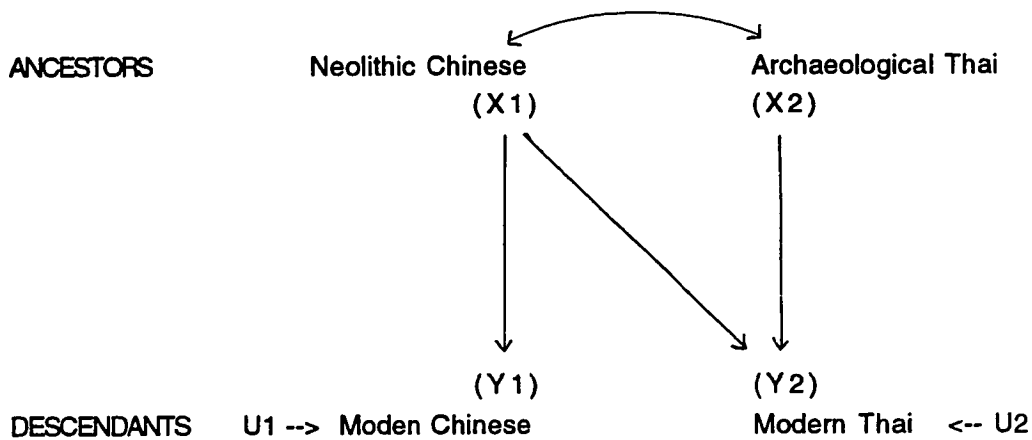


Figure 3. Path Diagram of Thai Origin

CHAPTER 3

ANALYSIS OF BIOLOGICAL AFFINITIES OF THE MODERN THAI

This chapter investigates the biological relationships among modern Thai, modern Chinese, archaeological Thai, and archaeological Chinese by using both metric and nonmetric craniofacial traits. The main objective of the analysis is to assess the biological affinities of the modern Thai population through the analysis of skeletal morphological traits.

The research addresses the following questions: (1) are there any differences in craniofacial morphology among modern and archaeological Thai and Chinese?; (2) do the patterns of biological affinity identified by craniofacial analysis agree or disagree with other indicators of biological affinity?; and (3) does the pattern of variation in craniofacial metric and nonmetric traits among these groups offer meaningful insights into ancestor-descendant relationships among these groups?

The analyses test the null hypothesis that there is no significant difference in craniofacial morphology among modern

Thai, modern Chinese, archaeological Thai, and archaeological Chinese. This null hypothesis should be true if these populations are recently derived from a common genetic stock.

Analyses of the data are designed to attempt to view the pattern of variation and to help elucidate genetic relatedness among archaeological and modern Thai/Chinese groups. The significance of left versus right side anatomical differences in facial traits are assessed by paired *t* tests and Pearson chi-square tests of independence. Each variable of each population group is examined to see whether the data behave normally using stem and leaf plots.

Some anomalies in the data are also viewed using boxplots.

Intergroup similarities between the study samples, considered one variable at a time, are examined using Tukey HSD multiple comparison tests and Pearson chi-square tests of independence.

Variable clusters that tend to be conveyed across the study groups are isolated by principal components analysis. The biological origin of the modern Thai is assessed using path analysis. Samples are first divided by geography (into Thai and Chinese) and chronology (into modern and archaeological groups), and then subdivided into males and females. All statistical analyses are computed using SYSTAT statistical software (Wilkinson 1989).

Bilateral Symmetry of Thai and Chinese Crania

Since the measurements and the observations of all cranial materials were recorded for left and right sides, the first data analysis step was to examine significant differences between the two sides. The samples were divided into four groups: modern Thai, modern Chinese, archaeological Thai, and archaeological Chinese. A paired-samples *t* test was applied to assess side-to-side differences by comparing the right side against the left side of the same individual. Significant differences between the two sides were expected to occur by chance ($\alpha = 0.05$). For cases in which no significant difference exists between the two sides, then values for the left side will be used in subsequent analyses. Right side values will be used when left side values are missing in order to maximize sample size. If a significant difference exists between the measured values for the same trait from the two sides, the average of the two sides will be used in further analyses.

Paired *t* tests of the study data show no significant differences between the right and left sides of skulls. Table 3 shows paired-samples *t* tests between left and right sides of Thai and Chinese skulls for both sexes. Of all fourteen metric traits, there are only five left and right pairs of facial metric traits used in this study, fmo-szm, fmo-izm, szm-izm, orb-h, and orb-b (descriptions of these

traits are given in the Appendix I). There is no significant difference at the 0.05 level between the left and right sided metric traits among the four groups. Therefore, the left side values for metric traits are used in comparisons among different groups of the sample population. However, right side metric trait values are used when the left side of the same individual is not available.

The next step is to subdivide the four sample groups by sex in order to reduce any effect sexual dimorphism may have on skull size. Paired-samples *t* tests of facial metric traits divided between the left and right side for Thai and Chinese males and females are presented in Tables 4 and 5, respectively. The male group shows no significant difference at the 0.05 level between the left and right side for metric traits. Therefore, the left side values for metric traits are used in comparisons among these groups.

As for the female group shown in Table 5, the result also indicates no significant difference at the 0.05 level between left and right side values for these 5 facial metric traits, with the exception of orbital breadth in archaeological Chinese. This group exhibits a value of $t = -2.439$, which exceeds -2.110 , the significance point for a two-tailed test at the 0.05 level. This significant value makes it worthwhile to reconsider the case. According to Table 5, there are two *t* tests for the female

archaeological Chinese group, therefore the effective probability value becomes $2(0.05) = 0.10$ or 10 percent (see Glantz 1992 for more detail on multiple comparisons). In order to compensate for this error, the significance of 0.05 should be divided by 2 (two t tests for this specific group), or $0.05/2 = 0.025$ or 2.5 percent. Thus, a value of $t = -2.439$ does not fall beyond the critical value of -2.567 (2.5 percent level with 17 degrees of freedom).

Given these results, the left side values for these traits are selected for later analyses, with right side values substituted when the left are missing.

Grouped Comparisons of Craniofacial Metric Traits

The next step is to describe the data and determine any significant differences between groups. Descriptions of each variable will be given by geographical and chronological groups as well as the sub-divided sex groups.

The 307 skulls examined in this study include 125 modern Thai, 70 modern Chinese, 46 archaeological Thai, and 66 archaeological Chinese. The modern Thai group is composed of 72 males and 37 females (the 16 cases of unknown sex are excluded in the analyses grouped by sex). The modern Chinese group contains 50 males and 20 females. The archaeological Thai group includes 28

males and 17 females (the 1 specimen of unknown sex is omitted in analyses grouped by sex). The archaeological Chinese group contains 41 males and 25 females.

First, patterning within and between groups was examined using stem and leaf plots (not shown here), as well as boxplots. Each variable of each group was examined to determine if the data behave normally and if there are any visible anomalies. The results indicate that the data for most measurements behave normally. Some values show long tails, but they are not skewed, as the values of the mean, median, and mode are relatively close to each other.

Comparisons between males and females of each group were made using boxplots. An advantage of the boxplot is that the graph is able to display the body of the data without influence from outliers (Emerson and Strenio 1983). The boxplots show that for all variable groups, males in general tend to be larger than females (see Figures 12–25 in Appendix II). According to McGill, et al. (1978), if the intervals, which are marked by notches of two boxplots, do not overlap, there is a significant difference at about the 5% level between the two population medians. The results of the boxplot comparisons show that the differences between males and females occur in all groups, i.e., modern Thai (12 variables of 14 variables = 86%), modern Chinese (5/14 = 36%), archaeological Thai (2/13 =

15%), and archaeological Chinese (7/11 = 64%). These differences between males and females suggest that the data should be grouped by sex in further analysed.

Several boxplot comparisons revealed interesting outliers. Two far outliers with low values occur in the measures of facial height (na-pr) for modern Thai males, and one far outlier with a low value occurs in the measurements of bizygomatic breadth (zy-zy) for archaeological Chinese females (see Figures 14–15 in Appendix II). The former values are still within the range of na-pr values for modern Thai females, and the values are considered possible for small persons. The latter value, however, is not possible for adults or children. This value may reflect an error in the published data. This extremely disproportional value for zy-zy (96.5 mm.), which is from an archaeological Chinese female (i.e., Davenkou 105), is deleted in the analyses described below.

Based on the presence of the above anomaly, I gave special attention to every outlier. Most values are normal except for an outlier of low value in inter-orbital breadth (int-or) for a modern Chinese female and an outlier of high value in inter-orbital breadth for a modern Chinese male. These values are taken from specimens that are provisionally of Turkish tribal origin, according to museum labels. Also, there is an occipital bun-like structure on these skulls.

Because of these features, I decided to remove one female and four male modern Chinese specimens, collected from the Field Museum, from further analyses.

Tables 6–8 show the means, standard deviations, and number of cases included in the comparisons of the combined-sex group, male group, and female group, respectively. Although the statistical results give the *F* probability values for each compared variable across the population groups, the significant differences computed between each population pair in this multiple comparison derive from the Tukey HSD test. Also, SYSTAT software uses the Tukey-Kramer adjustment for unequal *n*'s (Wilkinson 1989). Pairs of means that are different at the 0.05 level are indicated here as statistically significant, which is shown with an asterisk in Table 9. The multiple comparison procedures in one-way analysis of variance indicate that 13 of 14 comparable variables differ significantly among female groups (with the exception of one trait--orbital height), and 13 of 14 comparable variables differ significantly among male groups (with the exception of one trait--biorbital breadth or upper facial breadth). Thus, 34.7% or 26/75 male pairs differ significantly, and 38.9% or 28/72 female pairs differ significantly (Table 9).

Generally, the Tukey HSD multiple comparison tests in one-

way analysis of variance show that all variables differ significantly across the four groups. However, when each group is further divided into male and female groups, the comparison tests indicate that the significant difference values for the upper facial breadth (fmo-fmo) and the orbital height (orb-h) are affected by sex.

The largest differential values in facial height (na-pr), nasal height (na-ns), and bizygomatic breadth (zy-zy) are found between archaeological Chinese and modern Thai, with the former larger than the latter for both male and female grouped comparisons. The largest differential values in maximum cranial breadth (eu-eu), and orbital breadth (orb-b) are found between archaeological Chinese and modern Chinese, with the former larger than the latter for both male and female grouped comparisons. The largest differential values in maximum cranial length (g-op), and interorbital breadth (int-or) are found between archaeological Thai and modern Thai, with the former larger than the latter for both male and female group comparisons. In short, the results indicate that archaeological populations tend to exhibit larger crania with correspondingly larger faces than modern groups. However, it should be noted that significant differences are rare between modern Chinese and archaeological Thai females, only the distance from superior zygomaxillare to inferior zygomaxillare (szm-izm) differ significantly between the two groups.

In males, facial height (na-pr), nasal height (na-ns), and nasal breadth (al-al) differ significantly between pair groups. Interorbital breadth (int-or) differs in both male and female group comparisons more than any other trait. Also, maximum cranial breadth (eu-eu) and orbital breadth (orb-b) differ significantly for more pairs in the female comparisons. In other words, differences among the male groups are centered on the length of the face as well as the shape of the nose, whereas female group differences are centered on the width of the skull and the shape of the eye orbits. Interorbital breadth, however, is more effective as a distinguishing characteristic than other traits used here.

In sum, data analyses suggest that sex does have an influence on the group comparisons. Males tend to be larger than females in almost all compared variables. Therefore, further analyses will consider males and females separately. The analyses also indicate that the face and skull of archaeological populations are larger than those of the modern groups. Specifically, the facial morphology of the modern Thai differs from the archaeological Chinese more than from the archaeological Thai. The implication is that modern Thai people are more closely related to archaeological Thai than to archaeological Chinese.

Bilateral Symmetry of Six Discrete Traits

Discrete traits were recorded for both sides of each facial skeleton. Thus, the first step is to determine if significant differences exist between the left and right sides. The samples were divided into three population groups: archaeological Thai, modern Thai, and modern Chinese. Archaeological Chinese are not scored for discrete traits because these are not available from the literature. Two-by-two tables compare the left and right score for each variable separated into male and female groups. Discrete traits are scored as either present or absent in the comparison. Missing values are excluded from the table. Again, as with the metric trait comparisons, if there is no significant difference between the two sides, the left side can be used in further analysis, and the right side substituted if the left side is missing. If there is a significant difference between the two sides for any discrete trait, then the left and right sides will be analysed separately.

Comparisons based on the left and right sides for six discrete variables (infra-orbital suture, os japonica, infra-orbital foramen, incisura malaris, shovel-shaped incisor, and four-cusped molar) are given for each population group, according to sex. Test statistics that include values for Pearson chi-square, probabilities, and number of cases are presented in Tables 10 and 11. Missing values

are excluded from the comparisons. Chi-square values are not calculated for those tables where all the values are present or absent.

Each two-by-two table used for a test of independence is constructed with two rows of left facial characters, presence or absence; and two columns of right facial characters also scored for presence or absence. Therefore, if the left and right sides are scored differently for any trait, the number of cases will appear in the boxes for absence/presence or presence/absence; if they show the same expression for a trait, the number of cases will appear in the boxes for absence/absence or presence/presence. If the number of cases in a row appear in only one of the absence/absence or presence/presence categories, then both left and right sides display no difference, and a chi-square value was not calculated.

Results indicate that discrete trait differences between left and right sides are not significant. Statistical results show all chi-square value are above 3.84 ($\chi^2 = 3.84$, $df = 1$, $p = 0.05$), which indicates that the null hypothesis of independence between discrete traits of the left and right side of the face should be rejected. In other words, chi-square values suggest a significant relationship between the left and right side for each compared trait. Therefore,

the expression of the left side trait on the left side are used in the analyses described below.

Grouped Comparisons of Dental and Facial Discrete Traits

Two-by-two tables were constructed to compare differences between populations for each discrete trait. Comparisons were drawn between two populations at a time. Pearson chi-square values test the null hypothesis that no population differs from any other ($H_0: AT = MT = MC$). The working hypothesis was that each group is different from every other ($H_1: AT \neq MT \neq MC$). The results shown in Table 12 indicate that archaeological and modern populations exhibit a few significant differences in trait expressions but both of the modern male populations show no traits that differ significantly at the $p \geq 0.05$ level.

In conclusion, comparisons of discrete traits disagree with metric trait comparisons (Table 9), especially with comparisons of modern groups. The comparisons disagree in that modern Thai and modern Chinese have a concordant relationship for discrete trait expression.

The Influence of Associated Traits in Craniofacial Variation

In order to understand the structure of a multivariate data

set, and to select a subset of quantitative associated variables that influence group division, a principal components analysis was performed. The correlation matrices was used to derive principal component loading values. In order to determine the suitability of variables for inclusion in a principal components analysis, comparable variables that show low correlation values of less than 0.3 with other variables were eliminated. This was done because it can be assumed that each variable is relatively highly correlated with other variable(s) (Frane and Hill 1976). In this case, comparable variables for all four population groups excluded the three measurements of malar bone (fmo-szm, fmo-izm, szm-izm), as well as maximum width of the maxilla (max-max). The malar measurements are not available in the archaeological Chinese group, and the maximum width of maxilla (max-max) shows too many missing values in the archaeological Thai group. Therefore, only ten variables (maximum cranial length [g-op], maximum cranial breadth [eu-eu], bizygomatic breadth [zy-zy], biorbital breadth [fmo-fmo], facial height [na-pr], nasal height [na-ns], nasal breadth [al-al], orbital height [orb-h], orbital breadth [orb-b], and interorbital breadth [int-or]), grouped by sex, were analyzed using Pearson correlation matrices. Although the correlation matrices indicate that some variables show low correlations with other variables,

none of them have coefficients of less than 0.3 (Tables 13–14).

The first three principal component loading values were retained for interpretation, following Kaiser's criterion (Kaiser 1960) of the size of the latent roots (eigenvalues) that exceed 1.00 for initial extraction. Tables 15 and 16 present the component loadings of the variables, eigenvalues, and percents of total variance for the first three principal components of the male and female groups, respectively.

The unrotated loadings are sorted by magnitude. Although varimax rotated loadings were computed, they do not offer any more interpretable structure than the original principal components. The relationships among variables do not change whether rotated or unrotated loadings are computed (Reyment and Joreskog 1993). Furthermore, both rotated and unrotated solutions explain "exactly the same amount of variation in variables" (Duntelman 1989:50).

The largest principal component in the male group suggests that overall facial features (bizygomatic breadth, biorbital breadth, nasal height, orbital breadth, facial height, nasal breadth, and orbital height) have the highest load. Interorbital breadth, which has the lowest loading value in the first component loading, has the highest value in the second component. Maximum cranial breadth (eu-eu) and cranial length (g-op), display higher loading values in the

third component. However, only the first and second components, which are most useful for accounting for patterns in the data, will be discussed here. The third component, which explains a smaller percentage of total variance than the first two components, can be considered negligible (Wilkinson 1989). Maximum cranial breadth (eu-eu) and cranial length (g-op) will not be included in any decomposition for the male groups. The first and second components account for 50.85% of the variance in the sample.

The first component for the female group also indicates that overall facial features have the highest loading values. The first composite variable for females includes six variables present in the male group (biorbital breadth, facial height, bizygomatic breadth, nasal height, orbital breadth, and orbital height). The loadings for females, however, include maximum cranial breadth instead of nasal breadth in the first component. The higher loading coefficients in the second component are maximum cranial breadth, interorbital breadth, cranial length, and nasal breadth. Maximum cranial breadth is already selected for the first component, thus interorbital breadth, cranial length, and nasal breadth, which are all negative values, are used as an associated trait of the second component. The two variables that show high loading values in the third component are already selected for the first component as well. Finally, only

the first and second components, which describe 53.33% of the total variance, will be discussed further.

These loadings are decomposed and given names according to the grouped variables. There are two groups of variables for both male and female samples. These are: “overall facial features” and “mid-facial features.” Although the variable composition of the male and female groups differs slightly, the majority of higher loading values are similar. Again, “overall facial feature” for males include bizygomatic breadth, biorbital breadth, nasal height, orbital breadth, facial height, nasal breadth, and orbital height; whereas “overall facial feature” for females includes maximum cranial breadth instead of nasal breadth. Also, “mid-facial feature” for males is the interorbital breadth; “mid-facial feature” for females refers to interorbital breadth, nasal breadth, and cranial length.

Internal consistency is determined by reliability coefficients obtained from decomposition in principal components analysis. Reliability estimates may be calculated by using Cronbach’s alpha, which is expressed as:

$$\alpha = N\bar{p} / [1 + \bar{p}(N-1)]$$

where N is equal to the number of items and $\bar{p}$ is equal to the mean inter-item correlation (Carmines and Zeller 1979:44). The average intercorrelation of the seven-item scale for “overall facial feature”

among males is $4.776/7 = 0.682$, $\alpha = 0.94$. “Mid-facial feature” for males show a value of $\alpha = 0.72$. “Overall facial feature” and “mid-facial feature” for females have values of alpha 0.94 and 0.77, respectively. As all of the alpha values are higher than 0.7, it is inferred that the composite variables are reliable indicators of group separation.

The first and second principal component scores for male groups are plotted in order to examine variation among the four population groups (see figure 4). These scores are derived from principal components score coefficients multiplied by the standardized data (Wilkinson 1989). The scattergram shows that the variables are widely spread, and the only clear pattern that may be seen visually is in the archaeological populations. The plots show that archaeological Chinese (filled squares) and archaeological Thai (circles) males are clustered on the positive side of the first component (none exceed -0.3), which indicates that both groups have a relatively large “overall facial feature” (face, nose, and eye size). These archaeological groups can be further divided by the second component because the archaeological Thai are present on only the positive side of the graph, indicating that they have a greater interorbital breadth than archaeological Chinese. Otherwise, the

scatterplots are too cluttered for visual detection of data patterning. The scatterplots comparing two populations at a time are provided in Appendix III.

Statistical differences for male group separation by two principal components demonstrated by the scattergram were calculated using the sum of the standardized variables from each composite variable as the input values for one-way analysis of variance (Frane and Hill 1976). Tukey HSD multiple comparisons of “overall facial feature” show significant differences between archaeological Chinese and both of the modern groups at the $p \leq 0.002$ level (Table 17). Also, the comparison of “mid-facial feature” confirms significant difference between archaeological Chinese and archaeological Thai ($p < 0.001$), archaeological Thai and modern Chinese ($p < 0.05$), archaeological Thai and modern Thai ($p < 0.001$), as well as modern Thai and modern Chinese ($p < 0.05$) (Table 18). While the amount of variance explained by both components is small, the statistical results indicate the importance of both “overall facial feature” and “mid-facial feature” in male groups separation.

The first and second component scores for female groups are plotted in Figure 5. The plots show that archaeological populations have larger “overall facial features” compared to the modern groups

as they are concentrated on the positive side of the first component. As with the male group comparisons, female archaeological Thai (circles) have wider “mid-facial feature” values than archaeological Chinese (filled squares). The negative axis on the second component in Figure 5 indicates a wider interorbital breadth, wider nasal breadth, and wider cranial length than the positive axis. Statistical differences are also calculated using the sum of the standardized variables from each composite variable in a one-way ANOVA. The Tukey HSD multiple comparison tests indicate significant differences between archaeological Chinese and modern Thai ($p < 0.001$) and archaeological Thai and modern Thai ($p = 0.025$) for “overall facial feature” (Table 19). Significant differences are also suggested between archaeological Chinese and archaeological Thai ($p < 0.05$), archaeological and modern Thai ($p = 0.001$), as well as modern Thai and modern Chinese ($p = 0.002$) for “mid-facial feature” (Table 20). It should be noted again that interorbital breadth, cranial length, and nasal breadth contribute to the female “mid-facial feature.”

In sum, principal component analyses for male and female groups show similar patterns of variation. Archaeological populations have larger “overall facial features” than modern groups, and archaeological Thai also have wider “mid-facial

features.” The group differences that are confirmed with Tukey HSD multiple comparisons in analyses of variance reveal that archaeological Chinese differ significantly from modern Thai in “overall facial features,” whereas archaeological Thai and modern Thai differ in “mid-facial features” for both male and female group comparisons. In other words, modern Thai differ from archaeological Chinese in the overall size of the face, nose, and eyes. Modern Thai, especially males, differ from archaeological Thai only in the interorbital region. In short, the principal component analyses reveal the importance of interorbital breadth for separating the population groups under study.

Ancestral-Descendant Relationships of the Modern Thai

The path diagram of Thai origins proposed in Chapter 2 (Figure 3) showed that modern Thai are descendants of both archaeological Chinese and archaeological Thai. In order to arrive at estimates of the degree of contribution from ancestral populations, Q-mode path analysis was used. This model uses the Q-mode method in order to illustrate relationships among populations instead of among variables (Loehlin 1987; Rummel 1970; Sneath and Sokal 1973). Initially, individual measurements are standardized because data sets contain a variable range of measurements (the same data set

used in principal components analyses is used here). The mean standardized values for each variable were taken and transposed. Thus, cases (row values) and variables (column values) assume a new position as column values (cases) and row values (variables). Pearson correlation matrices were computed in the form of Q-mode correlation coefficients as shown in Tables 21–23 for combined-sex groups, male groups, and female groups, respectively. Table 21 indicates that the modern Thai exhibit positive correlation with the archaeological Chinese, the modern Chinese exhibit positive correlation with the archaeological Thai, and the other pairs are negatively correlated. Table 22 indicates that modern Thai males are positively correlated with archaeological Thai males, but other male pairs are negatively correlated with each other. Table 23 indicates that modern Thai females are positively correlated with archaeological Chinese females, whereas modern Chinese females are positively correlated with archaeological Thai females. However, only the correlation between the female archaeological Chinese group and the female modern Chinese group is considered significant based on Bonferroni adjusted probabilities at the $p < 0.05$ level.

As may be seen in Table 21, the path coefficient between the two archaeological populations is -0.61 , and it is -0.700 for the two

Chinese populations. Path coefficients between modern Thai and the two archaeological populations are 0.315 and -0.029. These values have been derived from regression analyses for modern Thai on archaeological Chinese and Thai, respectively (Table 24).

Path coefficients for unknown factors (U_1 and U_2) can be calculated from the formulae:

$$\text{path } U_1 = \sqrt{1-R^2_{Mc.Ac}} = \sqrt{1-0.490} = 0.714;$$

$$\text{and path } U_2 = \sqrt{1-R^2_{Mt.AtAc}} = \sqrt{1-0.111} = 0.943$$

where Mc is Modern Chinese, Ac is Archaeological Chinese, Mt is Modern Thai, and At is Archaeological Thai.

In order to determine the percentage of the variance that cannot be explained by this diagram, the path coefficients from the residual factors are squared (Bohmstedt and Knoke 1988).

Therefore, 51% of the variance in the modern Chinese sample cannot be explained by this model, and 89% of the variance in the modern Thai sample cannot be explained by this model (Figure 6).

In Table 22 for the male groups, the path coefficient between the two archaeological populations is -0.475, and between the two Chinese populations is -0.467. The path coefficients between the modern Thai and the two archaeological populations are 0.022 and 0.051, which have been derived from regression analysis for modern Thai on archaeological Chinese and Thai, respectively (Table 25).

Path coefficients for the unknown factors are 0.884 for U_1 and 0.999 for U_2 indicating that 78% of the variance in modern Chinese males cannot be explained by this model, and essentially 100% of the variance in modern Thai males also cannot be explained by this model (Figure 7).

In Table 23 (female groups), the path coefficient between the two archaeological populations is -0.57 , and between the two Chinese populations is -0.841 . The latter value is considered significant based on Bonferroni adjusted probabilities which means that the archaeological and modern Chinese populations exhibit high relatedness. The path coefficients between modern Thai and the two archaeological populations are -0.012 and -0.366 , which have been derived from regression analysis for modern Thai on archaeological Chinese and Thai, respectively (Table 26). The path coefficients for the unknown factors are 0.540 for U_1 and 0.933 for U_2 . This indicates that only 29% of the variance in modern Chinese females cannot be explained by this model, and 87% of the variance in modern Thai females also cannot be explained by this model (Figure 8).

In conclusion, the path diagrams indicate that there are unknown ancestral groups for the modern Thai that are not included in the Thai origin model used in this study. The model shows that the correlations between the modern Thai and both the

archaeological populations are quite low. However, the correlation between the modern Thai and the archaeological Thai is higher than the correlation between the modern Thai and the archaeological Chinese only in the male model (Figure 7). The unknown factors, which represent populations not included in this study, show very high correlation coefficients with the modern Thai in all models. In short, path analyses imply that neither archaeological group, Thai or Chinese, is the primary ancestral group for the modern Thai.

Table 3

Paired-Samples *t* tests between the Left and Right Sides
of Male and Female Thai and Chinese Crania

Facial trait	Thai						Chinese					
	modern			archaeological			modern			archaeological		
	<i>t</i>	<i>p</i>	<i>n</i>	<i>t</i>	<i>p</i>	<i>n</i>	<i>t</i>	<i>p</i>	<i>n</i>	<i>t</i>	<i>p</i>	<i>n</i>
FMO-SZM	0.115	0.908	112	1.413	0.179	15	0.942	0.350	69			
FMO-IZM	1.259	0.211	117	0.511	0.617	15	-0.163	0.871	69			
SZM-IZM	-0.567	0.572	111	0.798	0.438	15	-0.485	0.629	69			
ORB-H	0.718	0.474	124	-1.094	0.297	12	0.846	0.400	70	-1.032	0.308	42
ORB-B	0.482	0.630	123	-1.483	0.166	12	-1.061	0.292	70	-1.351	0.184	45

Note: See Appendix I for detailed descriptions of each facial trait.

Table 4

Paired-Samples *t* tests between the Left and Right Sides
of Male Thai and Chinese Crania

Facial trait	Thai						Chinese					
	<u>modern</u>			<u>archaeological</u>			<u>modern</u>			<u>archaeological</u>		
	<i>t</i>	<i>p</i>	<i>n</i>	<i>t</i>	<i>p</i>	<i>n</i>	<i>t</i>	<i>p</i>	<i>n</i>	<i>t</i>	<i>p</i>	<i>n</i>
FMO-SZM	0.395	0.694	62	0.739	0.479	10	0.396	0.694	49			
FMO-IZM	0.175	0.861	67	1.134	0.286	10	-0.917	0.364	49			
SZM-IZM	-0.967	0.337	61	0.818	0.434	10	-0.245	0.807	49			
ORB-H	0.504	0.616	72	-0.150	0.886	6	0.724	0.472	50	-0.906	0.373	26
ORB-B	-0.933	0.354	72	-0.716	0.506	6	-1.075	0.287	50	0.744	0.464	27

Note: See Appendix I for detailed descriptions of each facial trait.

Table 5

Paired-Samples *t* tests between the Left and Right Sides
of Female Thai and Chinese Crania

Facial trait	Thai						Chinese					
	<i>t</i>	<i>p</i>	<i>n</i>	<i>t</i>	<i>p</i>	<i>n</i>	<i>t</i>	<i>p</i>	<i>n</i>	<i>t</i>	<i>p</i>	<i>n</i>
FMO-SZM	-0.472	0.640	36	1.725	0.160	5	1.291	0.212	20			
FMO-IZM	-1.982	0.055	36	-1.826	0.142	5	0.964	0.347	20			
SZM-IZM	-0.800	0.429	36	0.304	0.777	5	-0.547	0.590	20			
ORB-H	1.733	0.092	36	-1.160	0.298	6	0.433	0.670	20	-0.591	0.564	16
ORB-B	0.478	0.636	35	-1.510	0.191	6	-0.398	0.695	20	-2.439	0.026	18

Note: See Appendix I for detailed descriptions of each facial trait.

Numbers in boldface indicate a significant difference between the left and right sides of the same individual at the $p \leq 0.05$ level.

Table 6

Summary Descriptions of Craniofacial Metric Traits for Male and Female
Modern and Archaeological Thai and Chinese Groups

Cranio- Facial trait	Thai						Chinese					
	modern			archaeological			modern			archaeological		
	$\bar{x}$	SD	n	$\bar{x}$	SD	n	$\bar{x}$	SD	n	$\bar{x}$	SD	n
G-OP	169.69	8.16	106	178.38	10.93	29	174.46	8.16	65	173.59	11.27	54
EU-EU	140.94	6.77	90	139.40	5.85	30	138.55	5.39	65	144.71	6.71	56
NA-PR	66.51	5.35	88	68.35	4.72	17	69.34	4.98	65	71.40	5.43	61
ZY-ZY	130.10	7.56	108	135.22	6.97	9	131.74	6.43	65	136.01	5.56	36
FMO-FMO	95.47	5.04	108	96.72	4.42	27	95.42	4.58	65	97.73	3.67	51
FMO-SZM	31.04	1.90	105	32.84	2.48	32	32.32	1.94	65	-	-	0
FMO-IZM	43.20	3.41	105	45.88	2.65	30	45.06	3.19	65	-	-	0
SZM-IZM	32.12	4.01	103	30.28	3.61	30	34.29	3.77	65	-	-	0
NA-NS	50.20	3.73	109	51.06	3.00	16	52.55	3.52	65	53.49	3.75	59
AL-AL	25.63	2.32	109	27.97	2.11	17	25.47	1.86	65	27.04	2.24	58

Table 6 (continued).

ORB-H	33.25	1.93	109	33.63	2.33	19	34.29	2.02	65	33.88	1.95	63
ORB-B	40.59	2.51	108	40.41	3.24	16	40.26	2.22	65	42.53	2.09	64
INT-OR	18.42	2.08	109	21.52	2.11	23	19.87	1.92	65	18.58	2.27	61
MAX-MAX	99.25	6.08	30	98.80	5.17	5	98.72	4.86	60	104.48	6.04	52

Note: See Appendix I for detailed descriptions of each craniofacial trait.

Table 7

Summary Descriptions of Craniofacial Metric Traits for Male
Modern and Archaeological Thai and Chinese Groups

<u>Cranio- Facial trait</u>	Thai						Chinese					
	<u>modern</u>			<u>archaeological</u>			<u>modern</u>			<u>archaeological</u>		
	<u>x</u>	<u>SD</u>	<u>n</u>	<u>x</u>	<u>SD</u>	<u>n</u>	<u>x</u>	<u>SD</u>	<u>n</u>	<u>x</u>	<u>SD</u>	<u>n</u>
G-OP	172.38	7.15	69	181.03	9.80	17	175.35	8.23	46	176.87	10.84	33
EU-EU	142.70	6.48	57	141.00	5.27	19	140.03	5.00	46	144.57	7.19	35
NA-PR	68.43	4.22	57	68.91	5.05	11	70.42	5.25	46	73.92	4.57	37
ZY-ZY	133.00	6.47	72	136.50	9.04	5	134.22	5.24	46	138.08	4.57	22
FMO-FMO	97.35	4.39	72	98.25	4.54	16	96.60	4.26	46	99.02	3.17	30
FMO-SZM	31.53	1.81	68	33.15	2.42	20	32.36	1.94	46	-	-	0
FMO-IZM	44.04	3.48	68	46.66	2.60	19	45.47	3.34	46	-	-	0
SZM-IZM	33.05	4.00	66	31.55	3.17	19	34.90	4.00	46	-	-	0
NA-NS	51.59	3.41	72	51.30	2.98	10	53.26	3.44	46	55.06	3.10	36
AL-AL	26.22	1.96	72	28.40	2.37	10	25.72	1.87	46	27.76	1.92	36

Table 7 (continued).

ORB-H	33.56	1.96	72	33.59	1.69	11	34.60	2.14	46	34.34	1.64	39
ORB-B	41.29	2.51	72	42.17	2.33	9	40.67	2.27	46	42.99	2.22	40
INT-OR	18.83	2.10	72	21.70	2.53	15	19.90	1.97	46	18.91	2.30	39
MAX-MAX	101.16	6.48	19	99.25	5.85	4	99.81	4.49	41	106.60	5.88	32

Note: See Appendix I for detailed descriptions of each craniofacial trait.

Table 8

Summary Descriptions of Craniofacial Metric Traits for Female Modern and
Archaeological Thai and Chinese Groups

Cranio- Facial trait	Thai				Chinese							
	$\overline{x}$	SD	n	$\frac{\text{archaeological}}{\text{modern}}$	$\overline{x}$	SD	n	$\frac{\text{archaeological}}{\text{modern}}$				
G-OP	164.68	7.49	37	174.63	11.76	12	172.32	7.79	19	168.43	10.15	21
EU-EU	137.91	6.25	33	136.64	6.01	11	134.95	4.61	19	144.93	6.00	21
NA-PR	62.97	5.47	31	67.33	4.27	6	66.71	3.00	19	67.49	4.26	24
ZY-ZY	124.29	6.16	36	133.63	3.82	4	125.74	4.95	19	132.75	5.54	14
FMO-FMO	91.71	4.08	36	94.50	3.28	11	92.58	4.13	19	95.88	3.60	21
FMO-SZM	30.15	1.75	37	32.09	2.59	11	32.24	1.99	19	-	-	0
FMO-IZM	41.65	2.68	37	44.55	2.26	11	44.03	2.60	19	-	-	0
SZM-IZM	30.45	3.50	37	28.09	3.36	11	32.79	2.84	19	-	-	0
NA-NS	47.50	2.73	37	50.67	3.27	6	50.82	3.18	19	51.04	3.38	23
AL-AL	24.50	2.55	37	27.36	1.65	7	24.87	1.75	19	25.88	2.28	22

Table 8 (continued).

ORB-H	32.65	1.75	37	33.69	3.14	8	33.55	1.53	19	33.14	2.20	24
ORB-B	39.18	1.87	36	38.14	2.90	7	39.26	1.79	19	41.77	1.62	24
INT-OR	17.62	1.82	37	21.19	0.96	8	19.79	1.84	19	17.99	2.12	22
MAX-MAX	95.96	3.57	11	97.00	-	1	96.37	4.91	19	101.07	4.66	20

Note: See Appendix I for detailed descriptions of each craniofacial trait.

Table 9

**Summary Comparisons of Craniofacial Metric Traits for
Modern and Archaeological Thai and Chinese Groups
Using the Tukey HSD Multiple Comparison Tests**

	<u>AC/AT</u>		<u>AC/MT</u>		<u>AC/MC</u>		<u>AT/MT</u>		<u>AT/MC</u>		<u>MT/MC</u>	
	m	f	m	f	m	f	m	f	m	f	m	f
<u>Cranio-</u> <u>Facial trait</u>												
G-OP	..	..	..	..	..	..	*	*	..	..	..	*
EU-EU	..	*	..	*	*	*	..	..	..	..	..	..
NA-PR	*	..	*	*	*	..	..	..	..	..	..	*
ZY-ZY	..	..	*	*	..	*	..	*	..	..	..	..
FMO-FMO	..	..	..	*	..	*	..	..	..	..	..	..
NA-NS	*	..	*	*	..	..	..	..	..	..	*	*
AL-AL	..	..	*	..	*	..	*	*	*	..	..	..
ORB-H	..	..	..	..	..	..	..	..	..	..	*	..
ORB-B	..	*	*	*	*	*	..	..	..	..	..	..
INT-OR	*	*	..	..	..	*	*	*	*	..	*	*
MAX-MAX	..	~	*	*	*	*	..	~	..	~	..	..
FMO-SZM	~	~	~	~	~	~	*	*	..	..	..	*
FMO-IZM	~	~	~	~	~	~	*	*	..	..	..	*
SZM-IZM	~	~	~	~	~	~	..	..	*	*	*	*

Note: AC = Archaeological Chinese, AT = Archaeological Thai, MC = Modern Chinese, MT = Modern Thai, and m = male, f = female (male and female are tested separately).

.. all comparisons tested are insignificant.

* the statistical significance level is less than 0.05.

~ comparisons are not made due to insufficient cases.

Table 10

**Chi-Square Tests between the Left and Right Sides
of Male Thai and Chinese Crania**

	<u>Archaeological Thai</u>			<u>Modern Thai</u>			<u>Modern Chinese</u>		
	X^2	p	n	X^2	p	n	X^2	p	n
<u>Variable</u>									
Infra-orbital suture	7.0	.01	7	42.9	.00	68	31.6	.00	46
Os japonica	--	--	10	45.3	.00	69	45.0	.00	45
Infra-orbital foramen	8.0	.01	8	--	--	71	--	--	46
Incisura malaris	5.0	.03	11	41.6	.00	70	34.7	.00	46
Shovel shaped Incisor	4.0	.05	4	19.0	.00	19	7.0	.01	7
4-cusps molar	12.0	.00	12	14.9	.00	21	--	--	8

Note: "--" represents "left = right"; test statistic is not computed because left and right show only one character of the trait with the same frequency.

Table 11

Chi-Square Tests between the Left and Right Sides
of Female Thai and Chinese Crania

	<u>Archaeological Thai</u>			<u>Modern Thai</u>			<u>Modern Chinese</u>		
	X^2	p	n	X^2	p	n	X^2	p	n
<u>Variable</u>									
Infra-orbital suture	--	--	5	19.6	.00	35	5.4	.02	19
Os japonica	--	--	5	9.2	.00	33	--	--	19
Infra-orbital foramen	6.0	.01	6	16.9	.00	36	--	--	19
Incisura malaris	6.0	.01	6	32.2	.00	36	11.0	.00	19
Shovel shaped Incisor	8.0	.01	8	--	--	9	--	--	6
4-cusps molar	11.0	.00	11	5.6	.02	15	6.0	.01	6

Note: "--" represents "left = right"; test statistic is not computed because left and right show only one character of the trait with the same frequency.

Table 12

Summary Comparisons of Discrete Traits for Archaeological Thai,
Modern Thai, and Modern Chinese Groups

	<u>AT/MT</u>		<u>AT/MC</u>		<u>MT/MC</u>	
	m	f	m	f	m	f
<u>Variable</u>						
Metopic suture	``	``	``	``	``	*
Infraorbital suture	``	*	``	*	``	``
Nasal suture	``	``	``	``	``	``
Os japonica	``	``	``	-	``	``
Infraorbital foramen	*	*	*	``	-	-
Subnasal character	*	``	*	``	``	``
Incisura malaris	``	``	``	``	``	*
Shovel shaped incisor	``	``	``	``	``	``
four-cusped molar	``	``	``	``	``	``
Rocker jaw	*	``	*	``	``	``

Note: AT = Archaeological Thai; MC = Modern Chinese; MT = Modern Thai; and m = male; f = female.

`` indicates $p \geq 0.05$ or the two populations have a significant relation on the character of the trait.

* indicates $p < 0.05$ or the two populations differ significantly from each other.

- indicates the two populations show only one character (same character) of the trait; test statistic is not computed.

Table 13

Pearson Correlation Matrix for Male Craniofacial Metric Traits

	G-O	E-E	N-P	Z-Z	F-F	N-N	A-A	O-H	O-B	I-O
<u>Trait</u>										
G-OP	1.00									
EU-EU	-0.11	1.00								
NA-PR	0.19	0.17	1.00							
ZY-ZY	0.26	0.42	0.44	1.00						
FMO-FMO	0.20	0.32	0.35	0.69	1.00					
NA-NS	0.27	0.15	0.76	0.49	0.38	1.00				
AL-AL	0.32	0.14	0.22	0.35	0.37	0.29	1.00			
ORB-H	0.25	0.16	0.37	0.20	0.24	0.41	0.05	1.00		
ORB-B	0.16	0.26	0.34	0.57	0.71	0.37	0.30	0.30	1.00	
INT-OR	0.19	-0.06	-0.01	0.23	0.38	0.00	0.15	0.07	-0.03	1.00

Note: Numbers in boldface indicate high correlations (≥ 0.3) with other variable(s). See Appendix I for detailed descriptions of each trait.

Table 14

Pearson Correlation Matrix for Female Craniofacial Metric Traits

	G-O	E-E	N-P	Z-Z	F-F	N-N	A-A	O-H	O-B	I-O
<u>Trait</u>										
G-OP	1.00									
EU-EU	-0.09	1.00								
NA-PR	0.31	0.35	1.00							
ZY-ZY	0.12	0.47	0.55	1.00						
FMO-FMO	0.27	0.39	0.52	0.66	1.00					
NA-NS	0.23	0.16	0.72	0.46	0.40	1.00				
AL-AL	0.21	0.04	0.27	0.36	0.27	0.17	1.00			
ORB-H	0.08	0.34	0.52	0.22	0.29	0.47	0.05	1.00		
ORB-B	0.18	0.41	0.29	0.40	0.71	0.19	0.13	0.25	1.00	
INT-OR	0.31	0.09	0.32	0.33	0.43	0.20	0.30	0.13	-0.06	1.00

Note: Numbers in boldface indicate high correlations (≥ 0.3) with other variable(s). See Appendix I for detailed descriptions of each trait.

Table 15

Loadings of Variables for the First Three Principal Components
(Male)

Variable	Overall Facial Feature	Mid-Facial Feature	Third Principal Component
Bizygomatic breadth (zy-zy)	0.82	0.17	-0.22
Biorbital breadth (fmo-fmo)	0.80	0.34	-0.23
Nasal height (na-ns)	0.74	-0.42	0.27
Orbital breadth (orb-b)	0.73	0.01	-0.29
Facial height (na-pr)	0.69	-0.47	0.21
Nasal breadth (al-al)	0.51	0.32	0.12
Interorbital breadth (int-or)	0.23	0.72	0.23
Maximum cranial breadth (eu-eu)	0.41	-0.11	-0.66
Maximum cranial length (g-op)	0.40	0.23	0.64
Orbital height (orb-h)	0.49	-0.35	0.27
Eigenvalues	3.75	1.34	1.28
% of total variance explained	37.45	13.40	12.81

Note: Numbers in boldface indicate the highest loading of variables for each component.

Table 16

Loadings of Variables for the First Three Principal Components
(Female)

	Overall Facial Feature	Mid-Facial Feature	Third Principal Component
<u>Variable</u>			
Biorbital breadth (fmo-fmo)	0.83	0.07	0.35
Facial height (na-pr)	0.82	-0.08	-0.37
Bizygomatic breadth (zy-zy)	0.78	0.06	0.21
Nasal height (na-ns)	0.68	-0.10	-0.52
Orbital breadth (orb-b)	0.59	0.43	0.42
Orbital height (orb-h)	0.55	0.24	-0.56
Maximum cranial breadth (eu-eu)	0.53	0.56	0.12
Maximum cranial length (g-op)	0.46	-0.57	0.11
Interorbital breadth (int-or)	0.36	-0.56	0.05
Nasal breadth (al-al)	0.41	-0.46	0.31
Eigenvalues	3.89	1.44	1.19
% of total variance explained	38.94	14.39	11.91

Note: Numbers in boldface indicate the highest loading of variables for each component.

Table 17

Matrix of Pairwise Comparison Probabilities Using Tukey HSD
Multiple Comparisons for Male "Overall Facial Feature"

	<u>Archaeological</u>		<u>Modern</u>	
	Chinese (AC)	Thai (AT)	Thai (MT)	Chinese (MC)
Archaeological Chinese (AC)	1.000			
Archaeological Thai (AT)	0.798	1.000		
Modern Thai (MT)	0.000	0.871	1.000	
Modern Chinese (MC)	0.002	0.947	0.866	1.000

Note: Numbers in boldface indicate a significance level of less than 0.05.

Table 18

Matrix of Pairwise Comparison Probabilities Using Tukey HSD
Multiple Comparisons for Male "Mid-facial Feature"

	<u>Archaeological</u>		<u>Modern</u>	
	Chinese (AC)	Thai (AT)	Thai (MT)	Chinese (MC)
Archaeological Chinese (AC)	1.000			
Archaeological Thai (AT)	0.000	1.000		
Modern Thai (MT)	0.998	0.000	1.000	
Modern Chinese (MC)	0.146	0.026	0.042	1.000

Note: Numbers in boldface indicate a significance level of less than 0.05.

Table 19

Matrix of Pairwise Comparison Probabilities Using Tukey HSD
Multiple Comparisons for Female "Overall Facial Feature"

	<u>Archaeological</u>		<u>Modern</u>	
	Chinese (AC)	Thai (AT)	Thai (MT)	Chinese (MC)
Archaeological Chinese (AC)	1.000			
Archaeological Thai (AT)	0.971	1.000		
Modern Thai (MT)	0.000	0.025	1.000	
Modern Chinese (MC)	0.064	0.212	0.260	1.000

Note: Numbers in boldface indicate a significance level of less than 0.05.

Table 20

Matrix of Pairwise Comparison Probabilities Using Tukey HSD
Multiple Comparisons for Female "Mid-facial Feature"

	<u>Archaeological</u>		<u>Modern</u>	
	Chinese (AC)	Thai (AT)	Thai (MT)	Chinese (MC)
Archaeological Chinese (AC)	1.000			
Archaeological Thai (AT)	0.042	1.000		
Modern Thai (MT)	0.291	0.001	1.000	
Modern Chinese (MC)	0.380	0.352	0.002	1.000

Note: Numbers in boldface indicate a significance level of less than 0.05.

Table 21

Q-mode Correlation Matrix for Male and Female
of the Four Population Samples

	<u>Archaeological</u>		<u>Modern</u>	
	Chinese (AC)	Thai (AT)	Thai (MT)	Chinese (MC)
Archaeological Chinese (AC)	1.000			
Archaeological Thai (AT)	-0.610	1.000		
Modern Thai (MT)	0.333	-0.221	1.000	
Modern Chinese (MC)	-0.700	0.250	-0.770	1.000

Table 22

Q-mode Correlation Matrix for Male of the Four Population Samples

	<u>Archaeological</u>		<u>Modern</u>	
	Chinese (AC)	Thai (AT)	Thai (MT)	Chinese (MC)
Archaeological Chinese (AC)	1.000			
Archaeological Thai (AT)	-0.475	1.000		
Modern Thai (MT)	-0.003	0.041	1.000	
Modern Chinese (MC)	-0.467	-0.165	-0.675	1.000

Table 23

Q-mode Correlation Matrix for Female of the Four Population Samples

	<u>Archaeological</u>		<u>Modern</u>	
	Chinese (AC)	Thai (AT)	Thai (MT)	Chinese (MC)
Archaeological Chinese (AC)	1.000			
Archaeological Thai (AT)	-0.570	1.000		
Modern Thai (MT)	0.196	-0.359	1.000	
Modern Chinese (MC)	*-0.841	0.542	-0.639	1.000

Note: * indicates $p < 0.05$ (Bonferroni adjusted probabilities).

Table 24

**Estimated Standardized Regression Coefficients for Male and Female
Modern Thai and Modern Chinese**

	Modern Thai	Modern Chinese
Archaeological Chinese	0.315	-0.700
Archaeological Thai	-0.029	
Coefficient of determination (R^2)	0.111	0.490

Table 25

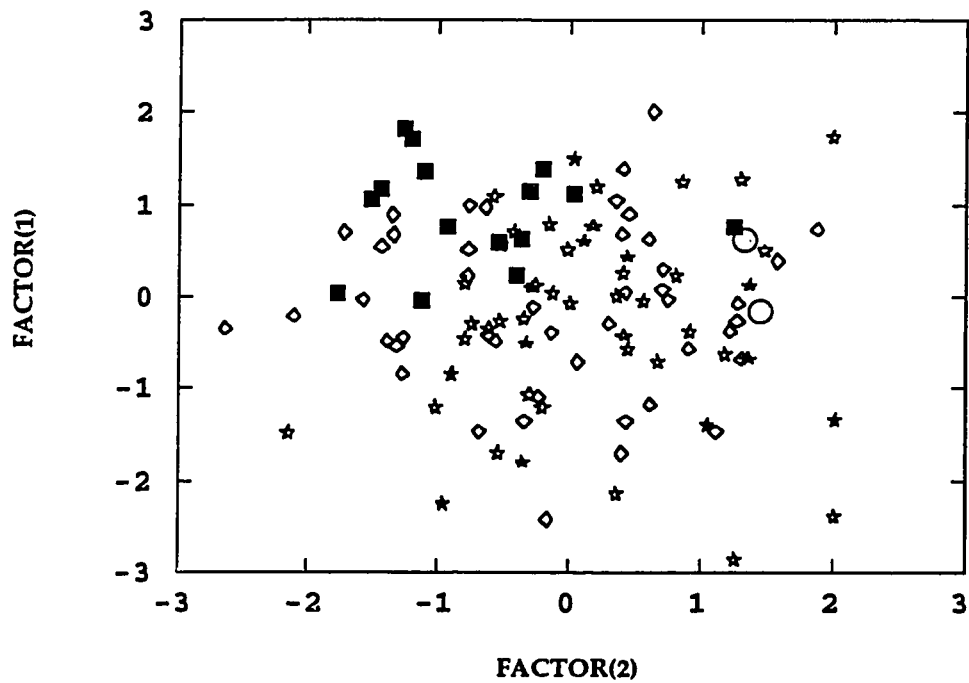
Estimated Standardized Regression Coefficients for Male
Modern Thai and Modern Chinese

	Modern Thai	Modern Chinese
Archaeological Chinese	0.022	-0.467
Archaeological Thai	0.051	
Coefficient of determination (R^2)	0.002	0.218

Table 26

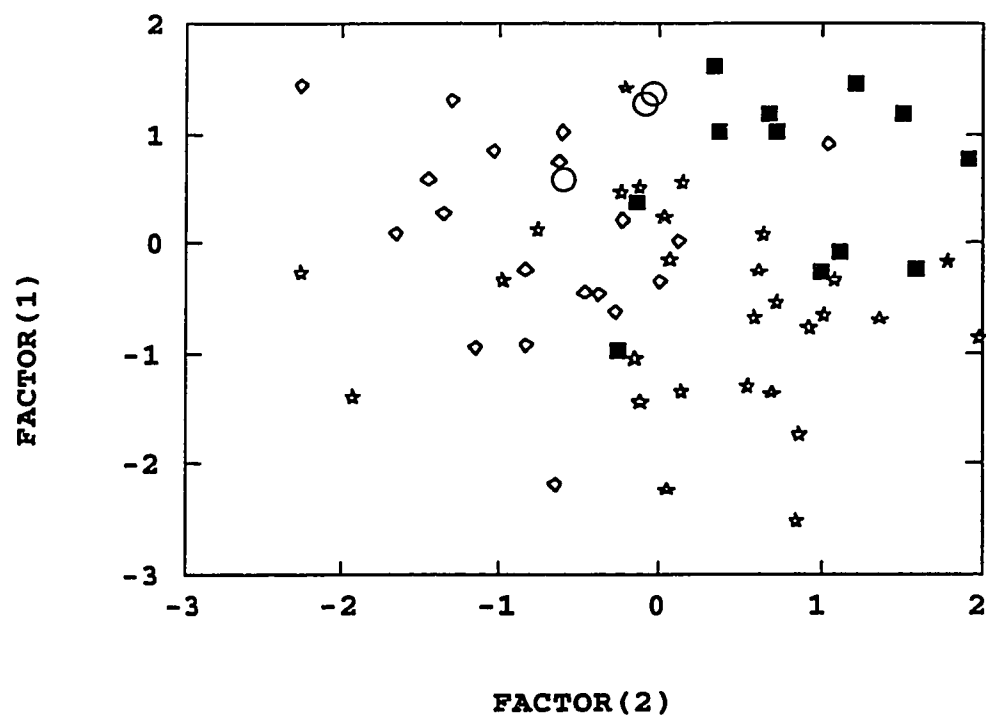
**Estimated Standardized Regression Coefficients for Female
Modern Thai and Modern Chinese**

	Modern Thai	Modern Chinese
Archaeological Chinese	-0.012	-0.841
Archaeological Thai	-0.366	
Coefficient of determination (R^2)	0.129	0.708



Circle = Archaeological Thai
 Star = Modern Thai
 Square = Archaeological Chinese
 Diamond = Modern Chinese

Figure 4. First and Second Component Scores Plots for Male Groups



- Circle = Archaeological Thai
- Star = Modern Thai
- Square = Archaeological Chinese
- Diamond = Modern Chinese

Figure 5. First and Second Component Scores Plots for Female Groups

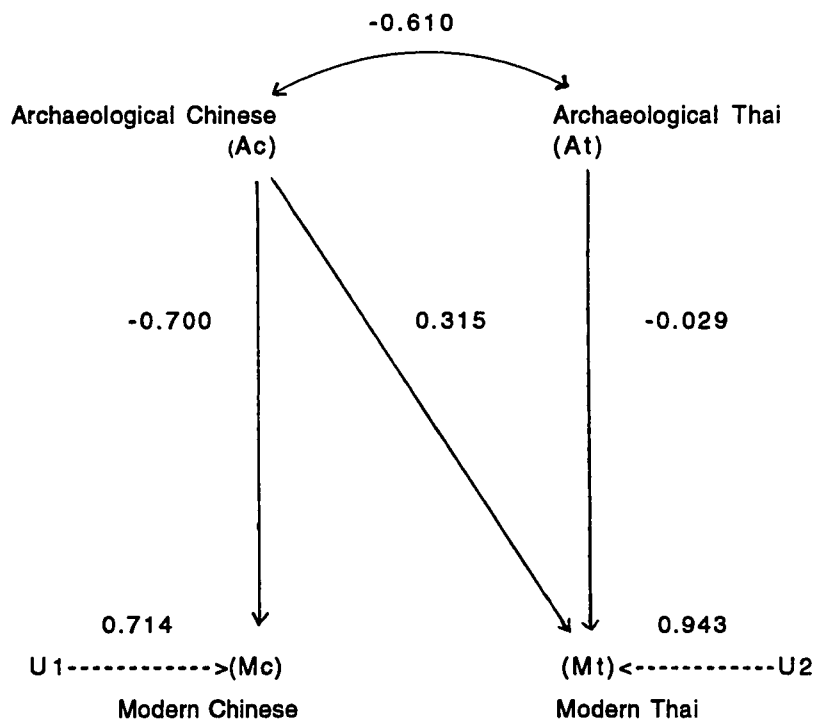


Figure 6. Path Diagram of Thai Origin with Numerical Estimates of Path Coefficients (Male and Female)

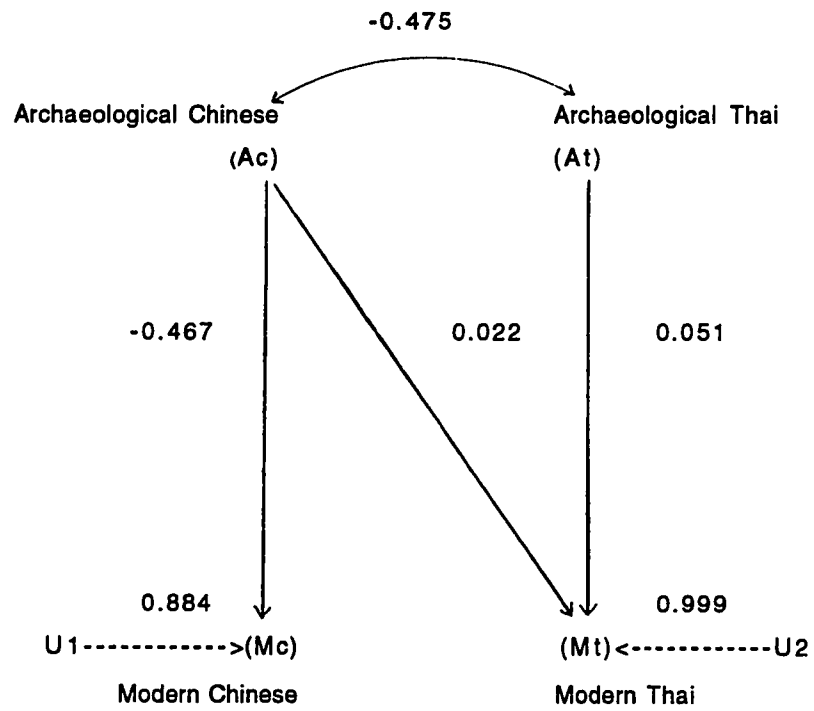


Figure 7. Path Diagram of Thai Origin with Numerical Estimates of Path Coefficients (Male)

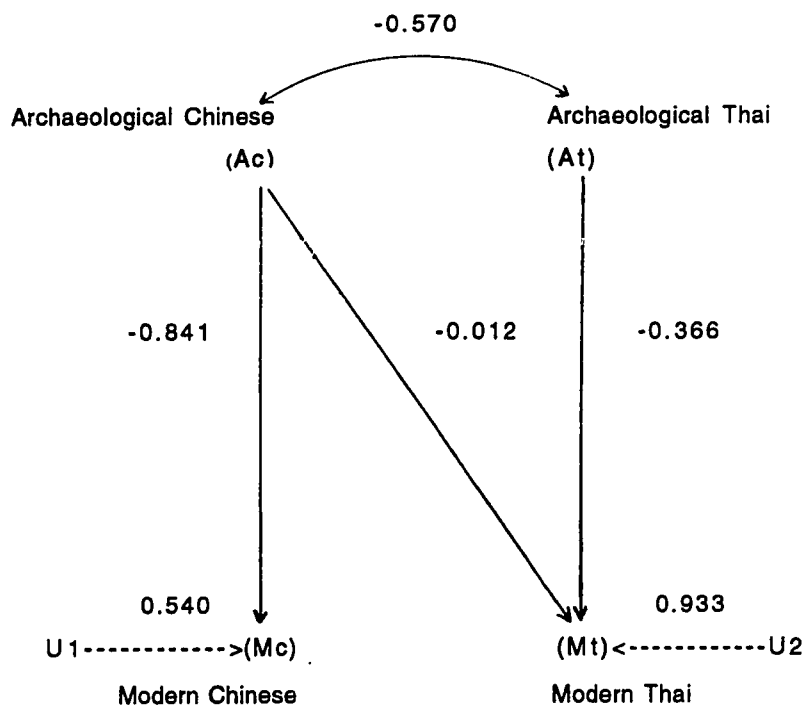


Figure 8. Path Diagram of Thai Origin with Numerical Estimates of Path Coefficients (Female)

CHAPTER 4

INTERPRETATION OF THE TEST RESULTS AND DISCUSSION OF THEIR IMPLICATIONS

The previous chapter presented the analysis of craniofacial morphological features for four population samples: archaeological Chinese, archaeological Thai, modern Chinese, and modern Thai. Biological relationships among these populations were estimated using four statistical measures: the chi-square test, the Tukey HSD multiple comparison test, principal components analysis, and path analysis. The results generally do not refute the endogenous hypothesis which proposes that modern Thai derive from autochthonous groups of people.

Craniofacial Morphological Differences between Modern Thai and Other Groups

In comparisons of craniofacial metric traits using the Tukey HSD multiple comparison tests, the modern Thai sample differed significantly from archaeological Chinese sample on more traits than they did from the archaeological Thai sample (Table 9). These

comparisons agreed with the results of a path analysis of the male groups exhibiting a higher correlation between modern Thai and archaeological Thai than between modern Thai and archaeological Chinese (Figure 7). The path analysis, however, indicates a high coefficient for unknown factors or other possible ancestral groups not included in this study. These other possible ancestral groups may include other early groups of population in mainland Southeast Asia, such as Neolithic populations of Laos and Vietnam. According to Pietrusewski (1978), the craniofacial metric traits of modern Thai and modern Chinese fall into different clusters, with modern Thai grouped with other modern Southeast Asians.

The finding that the modern Thai sample is closer biologically to archaeological Thai than to archaeological Chinese samples conflicts with the results of Li and colleagues (1991). Using nineteen craniofacial metric traits and emphasizing nasal area in the male comparison, Li and his colleagues found that modern Thai show less similarity to archaeological Thai than to archaeological Chinese. Nevertheless, they pointed out that such a result may be due to the small sample size for each archaeological group ($N = 2$). The present study, using fewer craniofacial metric traits but larger sample sizes (sizes in the range of 4 to 40 for archaeological groups), suggests that Li's small sample size may have affected his

result.

The comparison of dental and facial discrete traits using Pearson's chi-square tests did not indicate a significant difference between the samples of modern Thai and modern Chinese males (Table 12). Although these results contradict the comparisons of metric traits, similar results for discrete cranial comparisons among East and Southeast Asians have been reported. Pietrusewski (1978) found that modern Thai and modern Chinese fall in different clusters on the basis of craniofacial metric traits, but that the two populations fall in the same large cluster on the basis of craniofacial discrete traits. He concluded that metric traits represent size differences rather than biological relatedness. His interpretation suggests the use of discrete traits is a stronger indicator of biological relatedness. Although similar results on this matter are obtained in the present study, I disagree with his interpretation.

In the present study, discrete trait comparisons reveal no difference between the two male modern populations, Thai and Chinese, but metric traits reveal some significant differences. The selected discrete traits used in this study may be common traits that cannot be distinguished between spatially and temporally linked populations. In other words, discrete traits are probably less

powerful than metric traits when applied to synchronic population comparisons. Metric traits, on the other hand, provide similar results of biological distance among Indians as serological traits do (i.e., the ABO, MN, Rh series, taste reaction, and color blindness factors) (Sanghvi 1953).

Wilkinson (1970) dealt with a similar problem in reconstructing biological distances of Native Americans by use of skeletal morphological metric and nonmetric traits. He demonstrated that discrete traits are unstable when dealing with variability and small sample size (Wilkinson 1970), and he recommends the use of metric traits to measure phenetic similarities among populations. Discrete traits should be used with caution because of the problems in interpretation suggested above as well as for methodological problems, e.g., determining scoring criteria, (Corruccini 1974; Ossenberrg 1974; Suchey 1975; Zegura 1975).

In sum, the application of different statistical analyses indicate that the modern Thai are more closely related to the archaeological Thai than to the archaeological Chinese on the basis of craniofacial metric trait comparisons. Discrete trait comparisons, however, indicate that the modern Thai display almost no significant difference from modern Chinese. The disagreement

between metric and discrete traits occurred only in the analyses of synchronic population comparisons. These results suggest that these discrete traits do not offer results as reliable as those of the metric traits.

Craniofacial Morphological Differences between Archaeological Thai and Other Groups

The archaeological Thai specimens exhibit less similarity to modern Thai than to modern Chinese in craniofacial metric comparisons. The similarities between archaeological Thai and modern Chinese found in this study support linguistic, archaeological, and dental hypotheses on the migration of Thailand's past populations. This finding may reflect early Thai population dispersion through present day South China because most of the modern Chinese skulls used in this study are southern Chinese. The result concurs with the hypotheses indicating Southeast Asia as the Austro-Tai homeland, a pre-Austronesian indigenous population in Thailand, as well as Turner's Sundadonty and Sinodonty.

According to linguistic evidence, South China was the area of most linguistic diversity of the Tai-kadai language group (Edmondson and Solnit 1988). There is also some linguistic evidence that there was ethnic diversity which may consequently have

resulted in biological admixture between Chinese and Tai-Kadai speakers. A linguistic hypothesis proposed by Benedict (1975) states that some Chinese words are borrowed from Austro-Tai. This suggests a cultural influence of Southeast Asia on China. Similar to the linguistic proposal, Turner (1989) used dental characteristics to postulate that Sundadonts gave rise to Sinodonts, in other words that the more generalized Southeast Asian dental traits gave rise to the more specialized Chinese dentitions. The archaeological evidence presented by Higham (1989) suggests that the early native people in Thailand practiced rice cultivation before the arrival of Austronesian speakers. He used grass pollen dated at 7,000 B.P. as evidence for incipient agriculture. The pollen was found near Kok Panom Di, a pre-bronze site where 4,000 year old wild rice was also recovered (Higham 1989). All of the above hypotheses can be summarized as: approximately 7,000 years ago, there were native populations in present day Thailand. They lived in an area of wild rice and they later cultivated rice. Some of the latter groups migrated to South China.

In this study, the results of craniofacial similarities between archaeological Thai and modern Chinese can be interpreted as the result of early Tai populations in southern China have interacted and mixed extensively with the Chinese. The early Tai may have lived

dispersively in the wild rice area where covered South China and the north of Southeast Asia. Currently, some groups of Tai speakers (e.g., Tai Cuang) remain in Southern China as living evidence of a long term occupation of an early Tai group in present-day South China.

The fewer similarities between archaeological Thai and modern Thai than between archaeological Thai and modern Chinese may be explained if the modern Thai are the result of biological admixture with various ethnic groups. It is also suggested, by path diagrams of Thai origin, that unknown factors or other population groups not included in this study play an important role in the derivation of modern Thai peoples.

The Patterns of Craniofacial Metric Trait Variation: Spatial and Chronological Aspects

Craniofacial metric expression shows a diminution of size over time. In other words, the face and skull of modern populations are smaller than those of ancient populations. This pattern of variation can be seen by principal components analyses (Figures 4–5). The cluster of archaeological groups to the plus side of the first component indicates that archaeological populations had relatively larger faces, noses, and eye-orbits, or “overall facial features,” than modern groups. The significant differences are also

confirmed by Tukey HSD multiple tests. It is possible that the “overall facial features” differences between modern populations and archaeological populations may only represent a general difference between populations of different time periods (Tables 17–19).

The more closely related populations are more difficult to differentiate into individual groups because of their high degree of similarity. One may notice that it is hard to recognize the differences other than those mentioned above and shown in Figures 4 and 5. The geographically closer population pairs (i.e., the archaeological and modern Thai) and the chronologically closer population pairs (the archaeological Thai and Chinese, as well as the modern Thai and Chinese) can be distinguished by principal components analyses. The Tukey HSD multiple comparisons for “mid-facial feature” indicate the differences for each sample pair at the significance level of less than 0.05 (Tables 18 and 20). The “mid-facial feature” is the equivalent to the second component in the principal components analysis, and in this analysis refers to interorbital breadth of males and interorbital breadth, nasal breadth, and cranial length of females. Please note the difference in diagrams in Figures 4 and 5: the positive side on the second principal component for males equals wider “mid-facial feature,” but the

negative side of the second principal component for females equals wider “mid-facial feature.” Both male and female comparisons using principal components analyses offer similar results, namely that archaeological Thai had significantly wider “mid-facial features” than archaeological Chinese; that archaeological Thai had significantly wider “mid-facial features” than modern Thai; and that modern Chinese had significantly wider “mid-facial features” than modern Thai.

The metric traits examined by principal components analyses not only aid in differentiating populations diachronically, but also synchronically. Although the two archaeological populations do not differ significantly in “overall facial features,” they do differ significantly in terms of “mid-facial features.” The two modern populations differ significantly in “mid-facial features” but not in the “overall facial features.”

In short, principal components analyses reveal that craniofacial metric traits have become smaller over time. The analyses indicate the importance of interorbital breadth for differentiating between populations; archaeological Thai and modern Chinese present a wider interorbital region than archaeological Chinese and modern Thai.

Conclusion of The Test Results

The results from different statistical measures indicate that the null hypothesis is false and there is a significant difference in craniofacial morphology among modern Thai, modern Chinese, archaeological Thai, and archaeological Chinese. Each group is different from every other. The principal components analysis demonstrates between-group differences in craniofacial morphology and also provides the best morphological traits for discriminating between populations. The path analysis, however, further assesses the ancestral-descendant relationships between modern Thai and archaeological groups and suggests that an as yet unknown ancestral population is not considered by this study.

The Implication of Craniofacial Morphology in Phylogenetic Reconstruction

Craniofacial morphology is useful in phylogenetic reconstruction. Bones and teeth remain as the hard evidence for past and present population comparisons. The methods of measuring metric traits and recording discrete traits are inexpensive; these observations can easily be made. Although neither the means of inheritance of the morphological traits nor the degree of genetic contribution to craniofacial traits are known, biological relatedness

can be estimated on the basis of these traits.

In the present study, interorbital breadth, or the width of the area between the eye sockets, represents the best discriminator for population comparisons for spatial and chronological comparisons for both sexes. Although this trait has not been noted as a useful feature for racial diagnosis, the importance of the interorbital region has been pointed out by many researchers. Brues (1990), for instance, observed and marked differences of nasal root contours, such as "Quonset hut," "tent," and "church with a steeple," to distinguish "Negroid," "Mongoloid," and "Caucasoid," respectively. Gill and Gilbert (1990) refer to their interorbital features method as the best discriminator to differentiate between White and Black or between White and American Indian. Their method includes maxillofrontal breadth, which is the same measurement as the interorbital breadth used in this study, along with naso-maxillofrontal subtense to obtain maxillofrontal index, one of the three indices used in their study.

The present study indicates that simple measurement is equally useful as a more complicated measurement. It can be observed that the interorbital region includes the base of the nasal bone where the nasal bridge originates and that it alone is a distinguishing feature between different racial groups. Generally, a

flat nose is concordant with a wider interorbital breadth which results in a flat, broad face, which can be observed in Asians and Africans. The Caucasian upper and mid facial area, however, is characterized by a steeper nose with a narrower interorbital region.

Another good indicator for racial differences is the zygomatic or malar bone, the cheek bone, which was mentioned in Chapter Two as an area comprising numerous typically Asian characteristics. Unfortunately, the three measurements taken of the zygomatic bone were not used throughout this dissertation because of insufficient comparable data. Each trait, frontomolare orbitale to superior zygomaxillare (fmo-szm), frontomolare orbitale to inferior zygomaxillare (fmo-izm), and superior zygomaxillare to inferior zygomaxillare (szm-izm), exhibits a number of statistically significant differences (Table 9). Significant differences occur between the archaeological Thai and modern Thai for fmo-szm and fmo-izm; between the archaeological Thai and modern Chinese for szm-izm; and between the modern Thai and modern Chinese for fmo-szm, fmo-izm, and szm-izm. Therefore, I recommend that the three zygomatic bone measurements be used in future research concerning craniofacial metric trait comparisons. It will be interesting to see whether these traits will be as effective an indicator of morphological differences between populations as the interorbital

breadth.

CHAPTER 5

CONCLUSIONS

The controversy concerning the origins and movements of the Thai has been going on for many decades. The debates center around two distinct hypotheses: the “immigrant” and “endogenous” hypotheses. The immigrant hypothesis proposes that the Thai people originated in China, while the endogenous hypothesis proposes that modern Thai people are derived from indigenous populations. While both hypotheses are based largely on historical records, the Thai government maintains the traditional immigrant hypothesis for the official version of Thai origins.

The history of Thailand prior to the establishment of the Sukhothai Kingdom (A.D. 1,200–1,300) has rarely been revised since Borihanthepthani (1968) claimed that after the movement of the Thai from the Altai Mountains (7,000 years B.P.), the last migration was from Yunnan, China (A.D. 1,300). However, this immigrant hypothesis has been refuted by archaeological, linguistic, and genetic evidence. This evidence has recently influenced new

editions of the Thai history. The new official version of the history of Thailand still maintains the proposed migration from China prior to the establishment of Sukhothai in the thirteenth century A.D., but it does not mention the proposed migration from the Altai. This information is still being disseminated today (Tourism Authority of Thailand 1991).

In place of the viewpoint that Thais have originated from the Chinese, an alternate possibility that Thais may be derived from aboriginal tribes or native peoples of the area has been proposed in this dissertation. The findings listed previously in Chapter 1 that refute the immigrant hypothesis are based heavily on cultural remains. I think that the question "Who are the ancestors of the modern Thai?" cannot properly be solved without regard to physical evidence of the peoples. Therefore, I have chosen to utilize skeletal remains to reconstruct the relationships between the past and present populations.

The main focus of this study was to test the hypothesis that modern Thais are more closely related to early people in China than to early people in Thailand. If early Thais migrated from China to settle within the contemporary boundaries of Thailand, modern Thais should appear more closely related to archaeological Chinese than to archaeological Thai. Conversely, if modern Thais are derived from

early indigenous people in Thailand, modern Thais should appear more closely related to archaeological Thai than to archaeological Chinese.

This study, therefore, used skeletal morphological methods to measure population migration. As discussed in Chapter 2, of the human skeleton, the skull was considered to yield the best data for measuring the biological relationships among human populations. Specifically, measurements of the face are most discriminating for determining racial identity (Chapter 2). Therefore, more facial traits were selected for this study than cranial traits. The traits I study are referred to as craniofacial traits in this dissertation.

Generally, the relative reliability of anthropometric measurements and the anthroposcopic method for measuring population affinities is disputed. Therefore, both metric and nonmetric traits were used as the basis for the comparisons in this study. Even though metric traits have been shown to give similar results of biological distance as serological traits (Sanghvi 1953), many measurements could not be taken from the archaeological skeletal populations due to the fragility of long buried bones.

Twenty-four craniofacial traits, i.e., fourteen craniofacial metric and ten craniofacial discrete traits (Appendix I), were selected for use in this study. Most of these metric traits are

standard measurements that are known to convey meaningful variation in phylogenetic studies (Giles 1976), and are the major variants among closely related but geographically dispersed populations (Hanihara 1985a, 1985b). Also, some of the selected discrete traits used in this study were considered to have a high degree of success in discriminating closely related populations (Pietrusewsky 1978; Pope 1991; Turner 1989).

The craniofacial traits were analysed by standard statistical methods, i.e., the chi-square test, the Tukey HSD multiple comparison test, principal components analysis, and path analysis. The results show that populations separated by time and space can be differentiated by craniofacial morphology. The differences among the four groups, archaeological Thai, archaeological Chinese, modern Thai, and modern Chinese, can be summarized as follows:

- 1) Modern Thai may be more biologically closely related to archaeological Thai than to archaeological Chinese. This interpretation has been drawn from the results of both the craniofacial metric comparisons using Tukey HSD multiple comparison tests and the results using path analysis. However, the discrete trait comparisons by Pearson's chi-square tests yielded the result that modern Thai and modern Chinese appear to be most closely related.

- 2) Archaeological Thai appear less dissimilar to modern Chinese than modern Thai by metric craniofacial trait comparisons. This result supports other linguistic and dental hypotheses concerning the early migration of peoples from Southeast Asia to South China (Benedict 1975; Turner 1989).
- 3) Craniofacial skeletal metric patterns change through time as revealed through principal components analyses. The trend is towards smaller modern populations as compared to larger craniofacial skeletons of the archaeological populations.

The results of the principal components analyses also point to interorbital breadth as one of the best population discriminators for both male and female comparisons. The results show that archaeological Thai and modern Chinese samples exhibit wider interorbital breadth than archaeological Chinese and modern Thai samples.

In sum, morphological analysis of craniofacial data in this study refute the immigrant hypothesis, but neither does the evidence clearly support the endogenous hypothesis. Path analysis indicates that all the potential ancestral groups of modern Thai are not included in the populations examined in this study. Speculation based on other research (Pietrusewsky 1978, 1994) contends that the possible ancestral groups for modern Thai include other early

Southeast Asians such as Neolithic populations of Laos and Vietnam.

Future Research

Skeletal population analysis has proved useful to assess population movement. However, the problem of the origins of the Thai will not be solved until further analyses of skeletal samples of other archaeological and modern Southeast Asians are performed. In addition, larger sample sizes of archaeological Thai from different time periods should be added to the statistical analysis.

Two new methods that researchers are using to obtain more information from archaeological skeletal populations are the extraction of DNA from bone (Hagelberg, et al. 1989), and the detection of blood proteins in ancient human bone (Cattaneo, et al. 1990). Both techniques are still in their infancy. Although the former has been applied to some archaeological human remains, the technique of nucleic-acid analysis will be hard to utilize with rare human fossils, as bone samples are partly destroyed in order to obtain the results. However, even if the new method is proved useful in offering equivalent results to craniofacial morphological analysis in measuring biological distance, the latter method will still be much more practical, due to the simple and inexpensive methods of data collection and analysis.

Conclusion

The study of Thai migration is the study of population movement. However, more attention has been paid solely to cultural remains than to physical (skeletal) remains; in fact skeletal remains have not been utilized in the study of population migrations in Thailand. The significance of this study is to call attention to the fact that skeletal remains should not be ignored. Their attributes contain a wealth of information if it can be accessed. The osteological perspective has significant implications for the study of past and present population relationships because it provides direct evidence of population movements, that supplements the indirect evidence available from cultural sources. In this study, the craniofacial traits used to estimate biological affinities are limited to samples of only four populations: modern and archaeological Thai and Chinese. The results refute the hypothesis that modern Thai have descended from populations immigrating to Thailand from China, but fail to clearly support the hypothesis that modern Thai are descended from indigenous groups in Thailand. In other words, the results of this study indicate that the immigrant hypothesis and the endogenous hypothesis are not mutually exclusive. More samples of neighbouring populations are, therefore, needed for further analysis of the origins of the modern Thai.

REFERENCES CITED

Amphan Kijgnam

- 1985 Model Samrab Wiwattanakan Khong Kan Phowplook Khaw Nai Achia Tawanwak Chiang Tai (โมเดลสำหรับวิวัฒนาการของการเพาะปลูกข้าวโนเอเซียตะวันออกเฉียงใต้ [Model for the Development of Rice Cultivation in Southeast Asia]). *Silpakorn* 29:17–26.

Anderson, D.

- 1987 A Pleistocene-Early Holocene Rock Shelter in Peninsular Thailand. *National Geographic Research* 3:184–198.
- 1988 Excavations of a Pleistocene Rockshelter in Krabi and the Prehistory of Southern Thailand. In P. Charoenwongsa and B. Bronson (eds.), *Prehistoric Studies: The Stone and Metal Ages in Thailand*, pp. 43–59. Bangkok: Amarin Printing Group.

Anderson, J.E.

- 1968 Skeletal “Anomalies” as Genetic Indicators. In D.R. Brothwell (ed.), *The Skeletal Biology of Earlier Human Populations*, pp. 135–147. London: Pergamon Press.

Angel, J.L., and J.O. Kelly

- 1990 Inversion of the Posterior Edge of the Jaw Ramus: New Race Trait. In G.W. Gill and S. Rhine (eds.), *Skeletal Attribution of Race: Methods for Forensic Anthropology*, pp. 33–39. Albuquerque: Maxwell Museum of Anthropology Anthropological Paper No. 4.

Ayers, H.G., R.L. Jantz, and P.H. Moore-Jansen

- 1990 Giles and Elliot Race Discriminant Functions Revisited: A Test Using Recent Forensic Cases. In G.W. Gill and S. Rhine (eds.), *Skeletal Attribution of Race: Methods for Forensic Anthropology*, pp. 65–71. Albuquerque: Maxwell Museum of Anthropology Anthropological Paper No. 4.

Baker, S.J., G.W. Gill, and D.A. Kieffer

- 1990 Race and Sex Determination from the Intercondylar Notch of the Distal Femur. In G. W. Gill and S. Rhine (eds.), *Skeletal Attribution of Race: Methods for Forensic Anthropology*, pp. 91–95. Albuquerque: Maxwell Museum of Anthropology Anthropological Paper No. 4.

Bayard, D.T.

- 1979 The Chronology of Prehistoric Metallurgy in North-East Thailand: Silabhumí or Samrddhabhumí? In R.B. Smith and W. Watson (eds.), *Early South East Asia*, pp. 3–14. New York: Oxford University Press.
- 1992 Models, Scenarios, Variables and Suppositions: Approaches to the Rise of Social Complexity in Mainland Southeast Asia, 700 B.C.–A.D. 500. In I. Glover, P. Suchitta, and J. Villiers (eds.), *Early Metallurgy, Trade and Urban Centres in Thailand and Southeast Asia*, pp. 13–38. Bangkok: White Lotus.

Bellwood, P.

- 1992 Southeast Asia before History. In N. Tarling (ed.), *The Cambridge History of Southeast Asia*. Vol. 1, *From Early Times to c.1800*, pp. 55–136. New York: Cambridge University Press.

Benedict, P.

- 1942 Thai, Kadai, and Indonesian. *American Anthropologist* 44:576–601.
- 1975 *Austro-Thai Language and Culture*. New Haven: Human Relations Area Files Press.

Berry, R.J.

- 1968 The Biology of Non-Metrical Variation in Mice and Men. In D.R. Brothwell (ed.), *The Skeletal Biology of Earlier Human Populations*, pp. 103–133. London: Pergamon Press.

Birkby, W.H.

- 1973 *Discontinuous Morphological Traits of the Skull as Population Markers in the Prehistoric Southwest*. Ph.D. Dissertation, University of Arizona. Ann Arbor: University Microfilms International, Inc.

Black, D.

- 1928 A Study of Kansu and Honan Aeneolithic Skulls and Specimens from Later Kansu Prehistoric Sites in Comparison with North China and other Recent Crania. *Palaeontologia Sinica*, Series D, 6(1):1–83.

Blust, R.

- 1988 The Austronesian Homeland: A Linguistic Perspective. *Asian Perspectives* 26:45–67.

Bohmstedt, G.W., and D. Knoke

- 1988 *Statistics for Social Data Analysis*. Itasca: F.E. Peacock Publishers, Inc.

Borihantheptani, Phra

- 1968 Prawat Chat Thai: Kwam Pen Ma Khaung Chat Thai Tang Tee Yuk Duekdamban (ประวัติชาติไทย: ความเป็นมาของชาติไทยตั้งแต่ยุคดึกดำบรรพ์ [*History of Thai Nation*])). Bangkok: Sinlapabannakhan.

Brace, C.L.

- 1978 Tooth Reduction in the Orient. *Asian Perspectives* 19: 203–219.

- Brace, C.L., M.L. Brace, Y. Dodo, K.D. Hunt, W.R. Leonard, Y.Y. Li, X.Q. Shao, S. Sangvichien, and Z.B. Zhang
 1991 Micronesians, Asians, Thais, and Relations: A Cranio-Facial and Odontometric Perspective. *Micronesica* Supplement 2:323–348.
- Brace, C.L., Y.Y. Li, S.L. Smith, K.D. Hunt, and Z.B. Zhang
 n.d. A Cranio-Facial Comparison of Circum-Pacific Peoples. In G.S. Krantz (ed.), *Human Evolution in the Pacific Region*, Pullman: Washington State University Press.
- Bronson, B.
 1985 Notes on the History of Iron in Thailand. *Journal of the Siam Society* 73:205–225.
- Brooks, S., R.H. Brooks, and D. France
 1990 Alveolar Prognathism Contour, An Aspect of Racial Identification. In G.W. Gill and S. Rhine (eds.), *Skeletal Attribution of Race: Methods for Forensic Anthropology*, pp. 41–46. Albuquerque: Maxwell Museum of Anthropology Anthropological Paper No. 4.
- Brothwell, D.R.
 1959 The Use of Non-Metrical Characters of the Skull in Differentiating Populations. *Bericht Tagung Deutsch Gesellschaft Anthropologie* 103:103–109.
- Brues, A.M.
 1990 The Once and Future Diagnosis of Race. In G.W. Gill and S. Rhine (eds.), *Skeletal Attribution of Race: Methods for Forensic Anthropology*, pp. 1–7. Albuquerque: Maxwell Museum of Anthropology Anthropological Paper No. 4.
- Carmines, E.G., and R.A. Zeller
 1979 *Reliability and Validity Assessment*. Sage University Paper Series on Quantitative Applications in the Social Sciences, Series No. 07–017. Beverly Hills: Sage Publications.

- Cattaneo, C., K. Gelsthorpe, P. Phillips, and R.J. Sokol
1990 Blood in Ancient Human Bone. *Nature* 347:339.
- Cavalli-Sforza, L.L., A. Piazza, P. Menozzi, and J. Mountain
1988 Reconstruction of Human Evolution: Bringing Together Genetic, Archaeological, and Linguistic Data. *Proceedings National Academy of Sciences* 85:6002–6006.
- Chang, K.C.
1971 *The Archaeology of Ancient China*. New Haven: Yale University Press.
1973 Radiocarbon Dates from China: Some Initial Interpretations. *Current Anthropology* 14:525–528.
- Chang, K.C., and M. Stuiver
1966 Recent Advances in the Prehistoric Archaeology of Formosa. *Proceedings National Academy of Sciences* 55: 539–543.
- Chang, T.T.
1976a The Origin, Evolution, Cultivation, Dissemination and Diversification of Asian and African Rices. *Euphytica* 25:425–441.
1976b The Rice Cultures. *Philosophical Transactions of the Royal Society of London, Series B*, 275:143–157.
- Chen, D.
1989 The Taxonomy of Neolithic Man and Its Phylogenetic Relationship to Later Paleolithic Man and Modern Man in China. *Human Evolution* 4:73–86.
- Chit Phumisak
1981 Kwam Pen Ma Khaung Kham Sayam, Thai, Lao, Lee Khom Lee Laksana Thang Sangkhom Khaung Chue Chon Chat (ความเป็นมาของคำสยาม, ไทย, ลาว และ ขอม และลักษณะทางสังคมของชนชาติ [The origins of the words Siam,

- Thai, Lao and Khmer: the social characteristics of ethnic names*) Bangkok: Duang Kamol.
- 1983 Sangkhom Thai Lum Meenam Chaophraya Kon Samai Sri Ayutthaya (สังคมไทยลุ่มแม่น้ำเจ้าพระยาก่อนสมัยศรีอยุธยา [*Thai Society along the Chao Praya River before Ayuthya Period*]). Bangkok: Mai Gnam.
- Condominas, G.
- 1990 *From Lawa to Mon, from Saa' to Thai: Historical and Anthropological Aspects of Southeast Asian Social Spaces*. Canberra: The Australian National University.
- Corruccini, R.
- 1974 An Examination of the Meaning of Cranial Discrete Traits for Human Skeletal Biological Studies. *American Journal of Physical Anthropology* 40:425–446.
- 1976 The Interaction between Non-Metric and Metric Cranial Variation. *American Journal of Physical Anthropology* 44:285–294.
- Curran, B.K.
- 1990 The Application of Measures of Midfacial Projection for Racial Classification. In G.W. Gill and S. Rhine (eds.), *Skeletal Attribution of Race: Methods for Forensic Anthropology*, pp. 55–57. Albuquerque: Maxwell Museum of Anthropology Anthropological Paper No. 4.
- Dahl, O.C.H.R.
- 1976 Proto-Austronesian. *Scandinavian Institute of Asian Studies*. Monograph Series No.15. London: Curzon Press.
- Davidson, J.H.C.S.
- 1979 Archaeology in Northern Viet-Nam since 1954. In R.B. Smith and W. Watson (eds.), *Early South East Asia*, pp. 98–124. New York: Oxford University Press.
- Diffloth, G.
- 1984 *The Dvaravati Old Mon Language and Nyah Kur*. Vol. 1,

Monic Language Studies. Bangkok: Chulalongkorn University Press.

Dodd, W.C.

1923 *The Thai Race*. Cedar Rapids: The Torch Press.

Dunn, F.L.

1967 The Current Status of Ethnographic, Genetic and Other Biomedical Research among the Primitive Ethnic Groups of South-East Asia. In P.T. Baker and J.S. Weiner (eds.), *The Biology of Human Adaptability*, pp. 533–563. Oxford: Clarendon Press.

Dunteman, G.H.

1989 *Principal Components Analysis*. Sage University Paper Series on Quantitative Applications in the Social Sciences, Series No. 07–069. Newbury Park: Sage Publications.

Dyen, I.

1962a The Lexicostatistical Classification of the Malayo-Polynesian Languages. *Language* 38:34–46.

1962b Comment on Oceanic Linguistics Today. *Current Anthropology* 3:402–405.

1963 The Position of the Malayopolynesian Languages of Formosa. *Asian Perspectives* 7:261–271.

Edmondson, J. A., and D.B. Solnit

1988 *Comparative Kadai: Linguistic Studies beyond Tai*. Summer Institute of Linguistics, Arlington: University of Texas.

Emerson, J., and J. Strenio

1983 Boxplots and Batch Comparison. In D.C. Hoaglin, F. Mosteller, and J. Tukey (eds.), *Understanding Robust and Exploratory Data Analysis*, pp. 58–96. New York: John Wiley & Sons.

Enlow, D.H.

- 1975 *Handbook of Facial Growth*. Philadelphia: W.B. Saunders Co.

Finnegan, M., and K. Coopridge

- 1978 Empirical Comparison of Distance Equations Using Discrete Traits. *American Journal of Physical Anthropology* 49:39–46.

Finnegan, M., and S.A. McGuire

- 1979 Classification Systems for Discrete Variables Used in Forensic Anthropology. *American Journal of Physical Anthropology* 51:547–553.

Fisher, T.D., and G.W. Gill

- 1990 Application of the Giles and Elliot Discriminant Function Formulae to a Cranial Sample of Northwestern Plains Indians. In G.W. Gill and S. Rhine (eds.), *Skeletal Attribution of Race: Methods for Forensic Anthropology*, pp. 83–90. Albuquerque: Maxwell Museum of Anthropology Anthropological Paper No. 4.

Flatz, G.

- 1967 Hemoglobin E: Distribution and Population Dynamics. *Humangenetik* 3:189–234.

Flatz, G., and S. Sringam

- 1964 Glucose-6-Phosphate Dehydrogenase Deficiency in Different Ethnic Groups in Thailand. *Annals of Human Genetics* 27:315–318.

Flatz, G., C. Pik, and S. Sringam

- 1965 Hemoglobin-E and B-Thalassemia: Their Distribution in Thailand. *Annals of Human Genetics* 29:151–170.

Flenley, J. R.

- 1985 Man's Impact on the Vegetation of Southeast Asia: The Pollen Evidence. In V.N. Misra and P. Bellwood (eds.),

Recent Advances in Indo-Pacific Prehistory, pp. 297–305. New Delhi: Oxford and IBH Publishing Co.

Frane, J.W., and M. Hill

- 1976 Factor Analysis as a Tool for Data Analysis. *Communications in Statistics—Theory and Methods* A5(6):487–506.

Gaherty, G.

- 1973 Discrete Traits, Cranial Measurements and Non-Biological Data in Africa. *American Journal of Physical Anthropology* 40:136 (abstract).

Gilbert, R., and G.W. Gill

- 1990 A Metric Technique for Identifying American Indian Femora. In G.W. Gill and S. Rhine (eds.), *Skeletal Attribution of Race: Methods for Forensic Anthropology*, pp. 97–99. Albuquerque: Maxwell Museum of Anthropology Anthropological Paper No. 4.

Giles, E.

- 1976 Cranial Variation in Australia and Neighboring Areas. In R.L. Kirk and A.G. Thorne (eds.), *The Origin of the Australians*, pp. 161–172. Canberra: Australian Institute of Aboriginal Studies.

Gill, G.W.

- 1984 A Forensic Test Case for a New Geographical Race Determination. In T.A. Rathbun and J.E. Buikstra (eds.), *Human Identification: Case Studies in Forensic Anthropology*, pp. 329–337. Springfield: Charles C. Thomas.
- 1986 Craniofacial Criteria in Forensic Race Identification. In K.J. Reichs (ed.), *Forensic Osteology: Advances in the Identification of Human Remains*, pp. 143–159. Springfield: Charles C. Thomas.

Gill, G.W., and B.M. Gilbert

- 1990 Race Identification from the Midfacial Skeleton: American Blacks and Whites. *In* G. W. Gill and S. Rhine (eds.), *Skeletal Attribution of Race: Methods for Forensic Anthropology*, pp. 47–53. Albuquerque: Maxwell Museum of Anthropology Anthropological Paper No. 4.

Gill, G.W., S.S. Hughes, S.M. Bennett, and B.M. Gilbert

- 1988 Racial Identification from the Midfacial Skeleton with Special Reference to American Indians and Whites. *Journal of Forensic Sciences* 33:92–99.

Glantz, S.A.

- 1992 *Primer of Bio-Statistics*. New York: McGraw-Hill, Inc.

Glover, I.C.

- 1979 The Late Prehistoric Period in Indonesia. *In* R.B. Smith and W. Watson (eds.), *Early South East Asia*, pp. 167–184. New York: Oxford University Press.
- 1985 Some Problems Relating to the Domestication of Rice in Asia. *In* V.N. Misra and P. Bellwood (eds.), *Recent Advances in Indo-Pacific Prehistory*, pp. 265–274. New Delhi: Oxford and IBH Publishing Co.

Golson, J.

- 1985 Agriculture Origins in Southeast Asia: A View from the East. *In* V.N. Misra and P. Bellwood (eds.), *Recent Advances in Indo-Pacific Prehistory*, pp. 307–314. New Delhi: Oxford and IBH Publishing Co.

Gorman, C.F.

- 1969 Hoabinhian: A Pebble-Tool Complex with Early Plant Associations in Southeast Asia. *Science* 163:671–673.
- 1971 The Hoabinhian and After: Subsistence Patterns in Southeast Asia during the Late Pleistocene and Early Recent Periods. *World Archaeology* 2:300–321.

- Grubb, R.
1970 *The Genetic Markers of Human Immunoglobulins*. New York: Springer.
- Hagelberg, E., B. Sykes, and R. Hedges
1989 Ancient Bone DNA Amplified. *Nature* 342:485.
- Hanihara, K.
1985a Geographic Variation of Modern Japanese Crania and Its Relationship to the Origin of Japanese. *Homo* 36:1–10.
1985b Origins and Affinities of Japanese Viewed from Cranial Measurements. In R.L. Kirk and E. Szathmary (eds.): *Out of Asia: Peopling the Americas and the Pacific*, pp. 105–112. Canberra: Australian National University Press.
- Hanihara, T.
1993 Population Prehistory of East Asia and the Pacific as Viewed from Craniofacial Morphology: The Basic Populations in East Asia, VII. *American Journal of Physical Anthropology* 91:173–187.
- Hershkovitz, I., B. Ring, and E. Kobylansky
1990 Measurements in Separating Human Populations. *American Journal of Physical Anthropology* 83:307–319.
- Higham, C.
1988 Prehistoric Metallurgy in Southeast Asia: Some New Information from the Excavation of Ban Na Di. In R. Maddin (ed.), *The Beginning of the Use of Metals and Alloys*, pp. 130–155. Cambridge, MA: MIT Press.
1989 *The Archaeology of Mainland Southeast Asia*. Cambridge: Cambridge University Press.
- Higham, C., and A. Kijngam
1984 *Prehistoric Investigations in Northeastern Thailand*. Oxford: British Archaeological Report, International Series, 231:698–895.
1985 New Evidence for Agriculture and Stock-Raising in

Monsoonal Southeast Asia. In V.N. Misra and P. Bellwood (eds.), *Recent Advances in Indo-Pacific Prehistory*, pp. 419–423. New Delhi: Oxford and IBH Publishing Co.

Hinkes, M.J.

- 1990 Shovel Shaped Incisors in Human Identification. In G.W. Gill and S. Rhine (eds.), *Skeletal Attribution of Race: Methods for Forensic Anthropology*, pp. 21–25. New Mexico: Maxwell Museum of Anthropology Anthropological Paper No. 4.

Hotelling, H.

- 1933 Analysis of a Complex of Statistical Variables into Principal Components. *Journal of Educational Psychology* 24:417–441; 498–520.

Howells, W.W.

- 1973 *Cranial Variation in Man. A Study Multivariate Analysis of Patterns of Difference among Recent Human Populations*. Cambridge, Massachusetts: Papers of the Peabody Museum of Archaeology and Ethnology, Harvard University, Vol. 67.
- 1983 Origin of the Chinese People: Interpretations of the Recent Evidence. In D.N. Keightley (ed.), *The Origins of Chinese Civilization*, pp. 297–319. Berkeley: University of California Press.
- 1989 *Skull Shape and the Map. Craniometric Analyses in the Dispersion of Modern Homo*. Cambridge, Massachusetts: Papers of the Peabody Museum of Archaeology and Ethnology, Harvard University, Vol. 79.

Hughes, D.R.

- 1967 Osteological Evidence Suggestive of the Origin of the Mongoloid Peoples. In W.G. Solheim (ed.), *Archaeology at the Eleventh Pacific Science Conference* (Tokyo 1966), pp. 1–10. Asian and Pacific Archaeology Series No. 1, Social Science Research Institute, Honolulu: University of Hawaii.

Hughes, S.S.

- 1980 Differences in Nasal Projections between American Indian and Caucasoid Crania. *Wyoming Contributions to Anthropology* 2:96–113.

Iscan, M.Y.

- 1990 A Comparison of Techniques on the Determination of Race, Sex and Stature from the Terry and Hamann-Todd Collections. In G.W. Gill and S. Rhine (eds.), *Skeletal Attribution of Race: Methods for Forensic Anthropology*, pp. 73–81. Albuquerque: Maxwell Museum of Anthropology Anthropological Paper No. 4.

Iscan, M. Y., and T.S. Cotton

- 1990 Osteometric Assessment of Racial Affinity from Multiple Sites in the Postcranial Skeleton. In G.W. Gill and S. Rhine (eds.), *Skeletal Attribution of Race: Methods for Forensic Anthropology*, pp. 83–90. Albuquerque: Maxwell Museum of Anthropology Anthropological Paper No. 4.

Ishida, H.

- 1992 Flatness of Facial Skeletons in Siberian and Other Circum-Pacific Populations. *Zeitschrift fur Morphologie und Anthropologie* 79:53–67.

Ishida, H., and Y. Dodo

- 1992 Differentiation of the Northern Mongoloid: The Evidence of Cranial Nonmetric Traits. In K. Hanihara (ed.), *Japanese as a Member of the Asian and Pacific Populations*, pp. 79–93. International Symposium 4. Kyoto: International Research Center for Japanese Studies.

Jackson, J.E.

- 1991 *A User's Guide to Principal Components*. New York: John Wiley & Sons, Inc.

Jones, R. B.

- 1970 Classifier Constructions in Southeast Asia. *Journal of the American Oriental Society* 90:1–12.

Kaiser, H.F.

- 1960 The Application of Electronic Computers to Factor Analysis. *Educational and Psychological Measurement* 20:141–151.

Kellock, W.L., and P.A. Parsons

- 1970 A Comparison of the Incidence of Minor Non-Metrical Cranial Variants in Australian Aborigines with Those of Melanesia and Polynesia. *American Journal of Physical Anthropology* 33:235–239.

Kelly, K.M.

- 1990 Gm Polymorphisms, Linguistic Affinities, and Natural Selection in Melanesia. *Current Anthropology* 31:201–219.

Kirk, R.L.

- 1986 Human Genetic Diversity in South-East Asia and the Western Pacific. In D.F. Roberts and G.F. De Stefano (eds.), *Genetic Variation and Its Maintenance*, pp. 111–133. Cambridge: Cambridge University Press.

Kirk, R.L., and L.Y.C. Lai

- 1961 The Distribution of Haptoglobin and Transferrin Groups in South and East Asia. *Acta Genetica et Statistica Medica* 11:97–105.

LeBar, F. M., G. C. Hickey, and J. K. Musgrave

- 1964 *Ethnic Groups of Mainland Southeast Asia*. New Haven: Human Relations Area Files Press.

Lehman, F.K.

- 1963 *The Structure of Chin Society*. Urbana: The University of Illinois Press. Illinois Studies in Anthropology No. 3.

- Li, C.C.
 1956 The Concept of Path Coefficient and Its Impact on Population Genetics. *Biometrics* 12:190–210.
- Li, Y.Y., C.L. Brace, Q. Gao, and D.P. Tracer
 1991 Dimensions of Face in Asia in the Perspective of Geography and Prehistory. *American Journal of Physical Anthropology* 85:269–279.
- Lie-Injo, L.E.
 1976 Genetic Relationships of Several Aboriginal Groups in Southeast Asia. In R.L. Kirk and A.G. Thorne (eds.), *The Origin of the Australians*, pp. 277–306. Canberra: Australian Institute of Aboriginal Studies.
- Livingstone, F.B.
 1967 *Abnormal Hemoglobins in Human Populations: A Summary and Interpretation*. Chicago: Aldine Publishing Company.
- Loehlin, J.C.
 1987 *Latent Variable Models: An Introduction to Factor, Path, and Structural Analysis*. Hillsdale: Lawrence Erlbaum Associates, Inc.
- Lukacs, J.R., and B.E. Hemphill
 1993 Odontometry and Biological Affinity in South Asia: Analysis of Three Ethnic Groups from Northwest India. *Human Biology* 65:279–325.
- Majumdar, R.C.
 1985 *Champa*. Delhi: Gian Publishing House.
- Martin, R.
 1928 *Lehrbuch der Anthropologie*. Jena: Gustav Fischer.
- Maspero, H.
 1912 Etude sur la Phonetique Historique de la Langue

Annamite. *Bulletin de l'Ecole Francaise d'Extreme-Orient* 12.1:1–127.

McGill, R., J.W. Tukey, and W.A. Larsen

1978 Variations of Box Plots. *The American Statistician* 32:12–16.

Meacham, W.

1983 Origins and Development of the Yueh Coastal Neolithic: A Microcosm of Culture Change on the Mainland of East Asia. In D.N. Keightley (ed.), *The Origins of Chinese Civilization*, pp. 147–175. Berkeley: University of California Press.

Mizoguchi, Y.

1986 Contributions of Prehistoric Far East Populations to the Population of Modern Japanese: A Q-mode Path Analysis Based on Cranial Measurements. In T. Akazawa and C.M. Aikens (eds.), *Prehistoric Hunter-Gatherers in Japan: New Research Methods*, pp. 107–136. Tokyo: The University Museum, The University of Tokyo, Bulletin No. 27.

Molto, J.E.

1979 The Assessment and Meaning of Intraobserver Error in Population Studies Based on Discontinuous Cranial Traits. *American Journal of Physical Anthropology* 51:333–344.

Morant, G.M.

1923 A First study of the Tibetan Skull. *Biometrika* 14:193–260.

Mourant, A.E.

1983 *Blood Relations: Blood Groups and Anthropology*. Oxford University Press.

- Na-Nakorn, S., V. Minnich, and A.I. Chernoff
 1956 Studies in Hemoglobin E. II. The Incidence of Hemoglobin E in Thailand. *Journal of Laboratory and Clinical Medicine* 47:490–498.
- Napoli, M.L., and W.H. Birkby
 1990 Racial Differences in the Visibility of the Oval Window in the Middle Ear. In G. W. Gill and S. Rhine (eds.), *Skeletal Attribution of Race: Methods for Forensic Anthropology*, pp. 27–31. Albuquerque: Maxwell Museum of Anthropology Anthropological Paper No. 4.
- Natapintu, S.
 1988 Current Research on Ancient Copper-Base Metallurgy in Thailand. In P. Charoenwongsa and B. Bronson (eds.), *Prehistoric Studies: the Stone and Metal Ages in Thailand*, pp. 107–124. Bangkok: Amarin Printing Group.
- Ossenberg, N.S.
 1974 Origins and Relationships of Woodland Peoples: The Evidence of Cranial Morphology. In E. Johnson (ed.), *Aspects of Upper Great Lakes Anthropology: Papers in Honor of Lloyd A. Wilford*, pp. 15–39. St. Paul: Minnesota Historical Society.
 1976 Within and between Race Distances in Population Studies Based on Discrete Traits of the Human Skull. *American Journal of Physical Anthropology* 45:701–715.
- Pearson, K.
 1901 On Lines and Planes of Closest Fit to Systems of Points in Space. *Philosophical Magazine and Journal of Science* 2:559–572.
- Phansomboon, S., E.W. Ikin, and A.E. Mourant
 1949 The ABO, Rh, and MN Blood Groups of the Siamese. *American Journal of Physical Anthropology* 7:563–568.

Pietrusewsky, M.

- 1978 A Study of Early Metal Age Crania from Ban Chiang, Northeast Thailand. *Journal of Human Evolution* 7:383–392.
- 1981 Cranial Variation in Early Metal Age Thailand and Southeast Asia Studied by Multivariate Procedures. *Homo* 32:1–26.
- 1993 Pacific-Asian Relationships: A Physical Anthropological Perspective. Paper presented at the *Conference on Asia-Mainland/Austronesian Connections.*, University of Hawaii, Hawaii.
- 1994 The People of Ban Chiang: An Early Bronze Site in Northeast Thailand. Paper presented at the *Indo-Pacific Prehistoric Association 15th Congress*, Chiang Mai, Thailand.

Pietrusewsky, M., Y.Y. Li, X.Q. Shao and N.G. Quyen

- 1992 Modern and Near Modern Populations of Asia and the Pacific: a Multivariate Craniometric Interpretation. In T. Akazawa, K. Aoki and T. Kimura (eds.), *The Evolution and Dispersal of Modern Humans in Asia*, pp. 531–558. Tokyo: Hokusensha.

Pigott, V.

- 1985 Pre-Industrial Mineral Exploitation and Metal Production in Thailand. *MASCA Journal* 3:170–174.

Pisit Charoenwongsa

- 1987 Mauradok Ban Chiang (มรดกบ้านเชียง [The Legacy of Ban Chiang]). Bangkok: Amarin Printing Group, Ltd.

Pookajorn, S.

- 1994 Human Activities and Environmental Change during the Late Pleistocene to Middle Holocene in Southern Thailand and Southeast Asia. Paper presented at the *Society for American Archaeology Meeting*, Anaheim, California.

Pookajorn, S., and anonymous

- 1991 *Preliminary Report of Excavation at Moh-Khiew Cave, Krabi Province, Sakai Cave, Trang Province and Ethno-archaeological Research of Hunter-Gatherer Group, Socall "Sakai" or "Semang" at Trang Province.* Bangkok: The Hoabinnian Research Project in Thailand.

Poolsuwan, S.

- 1991 *Malaria and the Evolution of Human B-Globin Polymorphisms in Southeastern Asia.* Ph.D. Dissertation, University of Michigan. Ann Arbor: University Microfilms International, Inc.

Pope, G.G.

- 1985 Evidence of Early Pleistocene Hominid Activity from Lampang, Northern Thailand. *Bulletin of Indo-Pacific Prehistorical Archaeology* 6:2–9.
- 1991 Evolution of the Zygomaticomaxillary Region in the Genus *Homo* and Its Relevance to the Origin of Modern Humans. *Journal of Human Evolution* 21:189–213.

Pope, G.G., S. Barr, A. Macdonald, and S. Nakabanlang

- 1986 Earliest Radiometrically Dated Artifacts from Southeast Asia. *Current Anthropology* 27:275–279.

Prachakitkorachak, P.

- 1919 Wa Duai Phasa Tang Tee Nai Sayam Prathet (ว่าด้วยภาษาตั้งแต่ในสยามประเทศ [*On the languages in Siam*]). Bangkok: Sophonphiphatanakorn.

Reids, L.R.

- 1988 Benedict's Austro-Tai Hypothesis: An evaluation. *Asian Perspectives* 26:19–34.

Reischauer, E.O., and J.K. Fairbanks

- 1960 *East Asia: The Great Tradition.* Vol. 1, *A History of East Asian Civilization.* Boston: Houghton Mifflin

Company.

Reyment, R., and K.G. Joreskog

1993 *Applied Factor Analysis in the Natural Sciences*.
Cambridge: Cambridge University Press.

Rhine, S.

1990 Non-Metric Skull Racing. In G. W. Gill and S. Rhine
(eds.), *Skeletal Attribution of Race : Methods for
Forensic Anthropology*, pp. 9–20. Albuquerque: Maxwell
Museum of Anthropology Anthropological Paper No. 4.

Rummel, R.J.

1970 *Applied Factor Analysis*. Evanston: Northwestern
University Press.

Sanchai Sangvichien

1971 Kalok Khon Thai: Kan Sueksa Tang Manutsaya Witthaya
Kayaphap (กะโหลกคนไทย: การศึกษาทางมานุษยวิทยา-
กายภาพ [*Thai Skulls: The study of Physical
Anthropology*]). M.D. Dissertation, Mahidol University,
Bangkok.

Sanghvi, L.D.

1953 Comparison of Genetical and Morphological Methods for
a Study of Biological Differences. *American Journal of
Physical Anthropology* 11:385–404.

Sangvichien, S.

1966a Neolithic Skeletons from Ban Kao, Thailand, and the
Problem of Thai Origins. *Current Anthropology* 7:234–
235.

1966b A Preliminary Report on Non-Metrical Characteristics
of Neolithic Skeletons Found at Ban Kao, Kanchanaburi.
The Journal of the Siam Society 54:1–8.

- Sanpitak, N., H. Delbruck, J. Muangintra, B. Winyar, and G. Flatz
 1972 Polymorphism of Erythrocyte Phosphoglucomutase, Adenylate Kinase and Adenosine Deaminase in Northern Thailand. *Humangenetik* 14:330–332.
- Saunders, S.R.
 1978 *The Development and Distribution of Discontinuous Morphological Variation of the Human Infracranial Skeleton*. Archaeological Survey of Canada Paper No. 81. Ottawa: National Museum of Man, Mercury Series.
 1989 Nonmetric Skeletal Variation. In M.Y. Iscan and K.A.R. Kennedy (eds.), *Reconstruction of life from the skeleton*, pp. 95–108. New York: Alan R. Liss, Inc.
- Schanfield, M.S.
 1980 The Anthropological Usefulness of Highly Polymorphic Systems: HLA and Immunoglobulin Allotypes. In J.H. Mielke and M.H. Crawford (eds.), *Current Developments in Anthropological Genetics*, Vol. 1, pp. 65–85. New York: Plenum Press.
- Schanfield, M.S., and H. Gershowitz
 1973 Nonrandom Distribution of Gm Haplotypes in East Asia. *American Journal of Human Genetics* 25:567–574.
- Shennan, S.
 1990 *Quantifying Archaeology*. Edinburgh University Press.
- Simmons, R.T.
 1976 The Biological Origin of Australian Aborigines: An Examination of Blood Group genes and gene Frequencies for Possible Evidence in Populations from Australia to Eurasia. In R.L. Kirk and A.G. Thorne (eds.), *The Origin of Australians*, pp. 307–328. Canberra: Australian Institute of Aboriginal Studies.
- Sirijaraya, S.
 1988 *Dermatoglyphic Genetics of Five Populations in*

Thailand. Ph.D. Dissertation, University of Kansas. Ann Arbor: University Microfilms International, Inc.

Sjovold, T.

- 1973 The Occurrence of Minor Non-Metrical Variants in the Skeleton and Their Quantitative Treatment for Population Comparisons. *Homo* 24: 204–233.
- 1977 Non-Metric Divergence between Skeletal Populations: The Theoretical Foundation and Biological Importance of C.A.B. Smith's Mean Measure of Divergence. *International Journal of Skeletal Research*, Vol. 4 (supplement 1). Stockholm: Osteological Research Laboratory, University of Stockholm.

Smith, R.B.

- 1979 Mainland South East Asia in the Seventh and Eighth Centuries. In R.B. Smith and W. Watson (eds.), *Early South East Asia*, pp. 443–456. New York: Oxford University Press.

Sneath, P.H.A., and R.R. Sokal

- 1973 *Numerical Taxonomy*. San Francisco: W.H. Freeman & Co.

Solheim, W.G., II

- 1971 New Light on a Forgotten Past. *National Geographic Magazine* 139:330-339.

Solheim, W.G, II, and M. Ayres

- 1979 The Late Prehistoric and Early Historic Pottery of the Khorat Plateau with Special Reference to Phimai. In R.B. Smith and W. Watson (eds.), *Early South East Asia*, pp. 63–77. New York: Oxford University Press.

Sood Sangvichien

- 1978 Panha Kan Khluanyai Khong Khon Thai (ปัญหาการเคลื่อนย้ายของคนไทย [*The problem of Thai migration*]). Bangkok: Roong Ruang Tham.

Sorensen, P.

- 1985 The Prehistory of Thailand. In C. Flon (ed.), *The World Atlas of Archaeology*, pp. 250–251. Boston: G.K. Hall & Co.

Srisak Vallibhotama

- 1988 Khaw: kab phattanakan khong rath nai pra thet Thai (ข้าว: กับพัฒนาการของรัฐในประเทศไทย [*Rice: On the development of State in Thailand*]). *Silpa-wattanatham*, special issue.
- 1991 Thainoi Thaiyai Thaisayam (ไทยน้อย ไทยใหญ่ ไทยสยาม [Little Thai, Big Thai, Siamese Thai]). In S. Wongthet (ed.), *Thai noi, Thai Yai, Thai Siam*, pp. 2–135. *Silpa-wattanatham*, special issue.
- 1992 Sayam Prathet: Phumlang Khong Prathet Thai Tang Tee Yuk Duekdamban Con Tueng Samai Khung Sri Ayutthaya Rach Anacak Sayam (สยามประเทศ: ภูมิหลังของประเทศไทย ตั้งแต่ยุคดึกดำบรรพ์จนถึงสมัยกรุงศรีอยุธยาราชอาณาจักรสยาม [*Siam: Thailand's Historical Background from Prehistoric Times to Ayuthya*]). *Silpa-wattanatham*, special issue.

Steinberg, A.G.

- 1969 Globulin Polymorphisms in Man. *Annual Review of Genetics* 3:25–52.

Stevens, C.M.

- 1983 *Non-Metric and Metric Analysis of Mandibular Morphology*. M.A. Thesis, University of Nevada, Las Vegas.

Suchey, J.M.

- 1975 *Biological Distance of Prehistoric Central California Populations Derived from Non-metric Traits of the Cranium*. Ph.D. Dissertation, University of California, Riverside. Ann Arbor: University Microfilms International, Inc.

Suchit Wongthet

- 1984 Khon Thai Mai Dai Ma Cak Nai (คนไทยไม่ได้มาจากไหน [Thais do not come from anywhere]). *Silpa-wattanatham*, special issue.
- 1986 Khon Thai Yu Thi Ni (คนไทยอยู่ที่นี้ [The Thais are here]). *Silpa-wattanatham*, special issue.
- 1987a Cek Pon Lao (เจ๊กปนลาว [Chinese and Lao mixed groups]) *Silpa-wattanatham*, special issue.
- 1987b Khon Thai Yu Thi Nai Bang (คนไทยอยู่ที่ไหนบ้าง [Where are the Thais?]). *Silpa-wattanatham*, special issue.
- 1991 Khon Thai Nai Usa Khane (คนไทยในอุษาคเนย์ [The Thais in the East]). In S. Wongthet (ed.), *Thai noi, Thai Yai, Thai Siam*, pp. 138–231. *Silpa-wattanatham*, special issue.

Suthiragsa, N.

- 1979 The Ban Chiang Culture. In R.B. Smith and W. Watson (eds.), *Early South East Asia*, pp. 42–52. New York: Oxford University Press.

Tien Uttayanang

- 1951 Kan Sueksa Porimat, Cranial Module, Khanad, Lee Indices Nai Kalok Khon Thai Lee cin (การศึกษาปริมาตร, cranial module, ขนาด, และ Indices ในกะโหลกศีรษะของคนไทย และจีน [The Study of Cranial Volume, Cranial Module, Size, and Indices of Thais and Chinese skulls]). M.D. Dissertation, Mahidol University, Bangkok.

Thurgood, G.

- 1985 Benedict's Work: Past and Present. In G. Thurgood, J. A. Matisoff, and D. Bradley (eds), *Linguistics of the Sino-Tibetan Area: the State of the Art*. Canberra: The Australian National University.

Tourism Authority of Thailand

- 1991 *Thailand: A Golden Wonderland*. Bangkok: Tourism Authority of Thailand.

Tsukada, M.

- 1966 Late Pleistocene Vegetation and Climate in Taiwan (Formosa). *Proceedings National Academy of Sciences* 55:543–48.
- 1967 Vegetation in Subtropical Formosa during the Pleistocene Glaciations and the Holocene. *Palaeogeography, Palaeo-climatology, Palaeoecology* 3:49–64.

Tu, Y.T., and Chen, L.F.

- 1978 Did the Conquest of Ta-Li-Kuo by Qubilai (Kublai Khan) Cause a Mass of the Tai Race to Migrate Southward? English Translation from Chinese. In S. Sangvichien *The problem of Thai migration*, pp. 57–77. Bangkok: Roong Ruang Tham.

Tuchinda, S., D.L. Rucknagel, S. Na-Nakorn, and P. Wasi

- 1968 The Thai variant and the distribution of alleles of 6-phosphogluconate dehydrogenase and the distribution of glucose 6-phosphate dehydrogenase deficiency in Thailand. *Biochemical Genetics* 2:253–264.

Turner, C.G., II

- 1989 Teeth and Prehistory in Asia. *Scientific American* (February):88–96.
- 1990 Major Features of Sundadonty and Sinodonty, Including Suggestions about East Asian Microevolution, Population History, and Late Pleistocene Relationships with Australian Aborigines. *American Journal of Physical Anthropology* 82:295–317.

Velleman P.F., and D.C. Hoaglin

- 1981 *Applications, Basics, and Computing of Exploratory Data Analysis*. Boston: Duxbury Press.

- Vos, G., R. Kirk, and A.G. Steinberg
 1963 The Distribution of the Gammaglobulin Types Gm(a), Gm(x), Gm(b), and Gm-like in South and Southeast Asia and Australia. *American Journal of Human Genetics* 15:44–52.
- Wales, H. G. Q.
 1937 Further Excavations at Pong Tuk (Siam). *Indian Art and Letter* 10:42–48.
 1964 Some Ancient Human Skeletons Excavated in Siam. A Correction. *Man* 37:89–90.
- Wasi, P.
 1983 Hemoglobinopathies in Southeast Asia. In J.E. Bowman (ed.), *Distribution and Evolution of Hemoglobin and Globin Loci*, pp. 179–208. New York: Elsevier.
- Wasi, P., S. Na-Nakorn, and A. Suingdumrong
 1967 A Studies on the Distribution of Haemoglobin E, Thalassaemias, and Glucoses-6-Phosphate Dehydrogenase Deficiency in North-eastern Thailand. *Nature* 214:501–502.
- White, J.C.
 1986 *A Revision of the Chronology of Ban Chiang and its Implications for the Prehistory of Northeast Thailand*. Ph.D. Dissertation, University of Pennsylvania. Ann Arbor: University Microfilms International, Inc.
- Wilkinson, L.
 1989 *SYSTAT: The system for Statistics*. Evanston: SYSTAT, Inc.
- Wilkinson, R.G.
 1970 *Biological Relationships among Middle and Late Woodland Populations in the Great Lakes Region*. Ph.D. Dissertation, University of Michigan. Ann Arbor: University Microfilms International, Inc.

Wolpoff, M.H., X.Z. Wu, and A.G. Thorne

- 1984 Modern *Homo sapiens* Origins: A General Theory of Hominid Evolution Involving the Fossil Evidence from East Asian. In F.H. Smith and F. Spencer (eds.), *The Origin of Modern Humans: A World Survey of the Fossil Evidence*, pp. 411–483. New York: Alan R. Liss, Inc.

Wood, W.A.R.

- 1959 A History of Siam. Bangkok: Chalermit Bookstore.

Wright, S.

- 1934 The Method of Path Coefficients. *Annals of Mathematical Statistics* 5:161–215.

Wu, X.Z., and Z.B. Zhang

- 1985 *Homo Sapiens* Remains from Late Palaeolithic and Neolithic China. In R.K. Wu and J.W. Olsen (eds.), *Palaeoanthropology and Palaeolithic Archaeology in the People's Republic of China*, pp. 107–133. Academic Press, Inc.

Wuff, K.

- 1934 Chinesisch und Tai. Sprachvergleichende Untersuchungen *Danske Videnskabernes Selskab, Historik-filologiske Meddelelser* 20.3. Copenhagen: Levin and Munksgaard.

Yan, Y.

- 1962 A Study of the Neolithic Human Skeletons from Huaxian, Shaanxi. *Acta Archaeologica Sinica* 2:85–104.
1972 The Neolithic Human Skeletons from the Dawenkou Site, Shandong. *Acta Archaeologica Sinica* 1:91–122.
1973 The Neolithic Human Skeletal Remains from Xixiahou. *Kao Ku Hsuen Pao* 2:91–126.

Yan, Y., C. Liu, and Y.M. Gu

- 1960a Study of the Neolithic Human Skeletons from the Baoji Site, Shaanxi. *Gu Jizhuidongwu yu Gu Renlei (Palaeo-vertebrata et Palaeoanthropologia)* 2:33–43.

Yan, Y., X.Z. Wu, C.Z. Liu, and Y.M. Gu

- 1960b A Study of Human Skeletons from Banpo, Xi'an, Shaanxi. *Kaogu* 9:36–47.

Yen, D.

- 1977 Hoabinhian Horticulture: The Evidence and the Questions from Northwest Thailand. In J. Allen, J. Golson, and R. Jones (eds.), *Sunda and Sahul: Prehistoric Studies in Southeast Asia, Melanesia and Australia*, pp. 567–599. London: Academic Press.

Zegura, S.

- 1973 A Comparison of Distance Matrices Derived from Craniometric Measurements and Cranial Observations. *American Journal of Physical Anthropology* 40:157 (abstract).
- 1975 Taxonomic Congruence in Eskimoid Populations. *American Journal of Physical Anthropology* 43:271–284.

Zhang, Y.Y., L.H. Wang, and X. Dong

- 1977 The Human Skulls from the Zhenpiyan Neolithic Site at Guilin, Guangxi. *Vertebrata Palasiatica* 15:4–13.

APPENDIX I
DEFINITIONS AND ILLUSTRATIONS OF MORPHOLOGICAL LANDMARKS
FOR THE CRANIOFACIAL METRIC AND DISCRETE TRAITS
USED IN THIS STUDY

Craniofacial Metric Traits

Alare-Alare (al-al) or Nasal Breadth. The distance from alare to alare (the most lateral points or the maximum width of the nasal aperture), measured by sliding calipers (Figure 9). This measurement is equivalent to Black's measurement #17 (Black 1928), Morant's NB (Morant 1923), and Martin's 54 (Martin 1928).

Euryon-Euryon (eu-eu) or Maximum Cranial Breadth. The maximum distance between the left and right euryon (the most prominence on the parietal bone), measured by spreading calipers (Figure 9). This measurement is equivalent to Black's measurement #2 (Black 1928), Morant's B (Morant 1923), and Martin's 8 (Martin 1928).

Frontomale Orbitale to Frontomale Orbitale (fmo-fmo). The distance of biorbital breadth between the left and right frontomale orbitale (the most anterior point where the frontal bone meets with the zygomatic bone), measured by sliding calipers (Figure 9). This measurement is equivalent to Black's measurement #22 (Black 1928) and Martin's 43-I (Martin 1928).

Frontomale Orbitale to Inferior Zygomaxillare (fmo-izm). The

distance from frontomolare orbitale to inferior zygomaxillare (the most inferior point on the zygomatico-maxillary suture), measured by sliding calipers (Figures 9–10). This measurement is equivalent to Black's measurement #18 (Black 1928).

Frontomolare Orbitale to Superior Zygomaxillare (fmo-szm). The distance from frontomolare orbitale to superior zygomaxillare (the most superior point on the zygomatico-maxillary suture), measured by sliding calipers (Figures 9–10).

Glabella-Opisthocranion (g-op) or Maximum Cranial Length. The maximum distance from glabella (the most anterior point on the frontal bone) to opisthocranion (the most posterior point on the occipital bone), measured by spreading calipers (Figure 10). This measurement is equivalent to Black's measurement #1 (Black 1928) and Martin's 1 (Martin 1928).

Interorbital Breadth (int-or). The distance between the left and right maxillofrontale (mf) or the point where the maxillofrontal suture intersected with the line of the eye orbit, measured by sliding calipers (Figure 9). This measurement is equivalent to Martin's 50 (Martin 1928).

Maximum Width of Maxilla Bone (max-max) or Facial Breadth. The distance between the left and right inferior zygomaxillare (izm), measured by sliding calipers (Figure 9). This measurement is equivalent to Black's measurement #20 (Black 1928), Morant's GB (Morant 1923), and Martin's 46 (Martin 1928).

Nasion-Nasospinale (na-ns) or Nasal Height. The distance from nasion (the intersected point of the nasofrontal suture and the midsagittal plane) to nasospinale (the lowest margin of the nasal aperture), measured by sliding calipers (Figure 10). This measurement is equivalent to Black's measurement #16 (Black 1928), Morant's NH (Morant 1923), and Martin's 55 (Martin 1928).

Nasion-Prosthion (na-pr) or Facial Height. The distance of mid-facial height from nasion (the point where the frontal bone meets with the inter-nasal suture) to prosthion (the most anterior point on the maxillary alveolar process above alveolare), measured by sliding calipers (Figure 10). This measurement is equivalent to Martin's 48 (Martin 1928), however, it is not equivalent to Black's measurement #15 because he defined the prosthion as "the lowest point" which is the alveolare, or "ids" (infra-dentale superius). This measurement has been adjusted in an archaeological Chinese group, the Zhenpiyan, Guangxi, by subtracting 2 mm. for correcting the "na-ids" (or "n-sd") to "na-pr."

Orbital Breadth (orb-b). The distance from maxillofrontale (mf) to ectoconchion (ec), this measurement should be parallel to upper and lower borders of the eye orbits, measured by sliding calipers (Figure 9). This measurement is equivalent to Black's measurement #56 (Black 1928), Morant's O-1 (Morant 1923), and Martin's 51 (Martin 1928).

Orbital Height (orb-h). The distance from the upper to the lower orbital borders, measured perpendicular to the orbital breadth, measured by sliding calipers (Figure 9). This measurement is equivalent to Black's measurement #58 (Black 1928), Morant's O-2 (Morant 1923), and Martin's 52 (Martin 1928).

Superior Zygomaxillare to Inferior Zygomaxillare (szm-izm). The distance from superior zygomaxillare to inferior zygomaxillare, measured by sliding calipers (Figures 9–10).

Zygion-Zygion (zy-zy) or Bizygomatic Breadth. The distance of bizygomatic breadth or the maximum facial breadth from zygion to zygion (the most lateral points on the left and right zygomatic arches), measured by spreading calipers (Figure 9). This measurement is equivalent to Black's measurement #4 (Black 1928), Morant's J (Morant 1923), and Martin's 45 (Martin 1928).

Craniofacial Discrete Traits

Four-cusped Molar. The lower second molar that has “four (+) cusped shape.”

Incisura Malaris. The notch-shape on the lateral margin of the maxillary bone (Figure 11).

Infraorbital Foramen. The small hole under the eye orbit on the maxillary bone (Figure 11).

Infraorbital Suture. The articulating line on the maxillary bone from the infraorbital foramen to the inferior margin of the orbit (Figure 11).

Metopic Suture. The articulating line that separates the frontal bone into left and right halves (Figure 11).

Nasofrontal Suture. The articulating line that separates frontal bone from nasal bones. The suture was observed as either “curved” or “omega” shape (Figure 11).

Os Japonica. A suture on the malar bone passing laterally either from the lower margin of the orbit or from the zygomaxillary suture (Figures 10–11).

Rocker Jaw. The mandible that can be moved like a rocking chair due to the curved edge of the inferior margin of the horizontal ramus.

Shovel-shaped Incisor. The shovel-shaped upper central incisor that has the enamel extension on the lingual surface.

Subnasal Character. The inferior border of nasal openture. It was observed as “blunt” or “sharp” character (Figure 10).

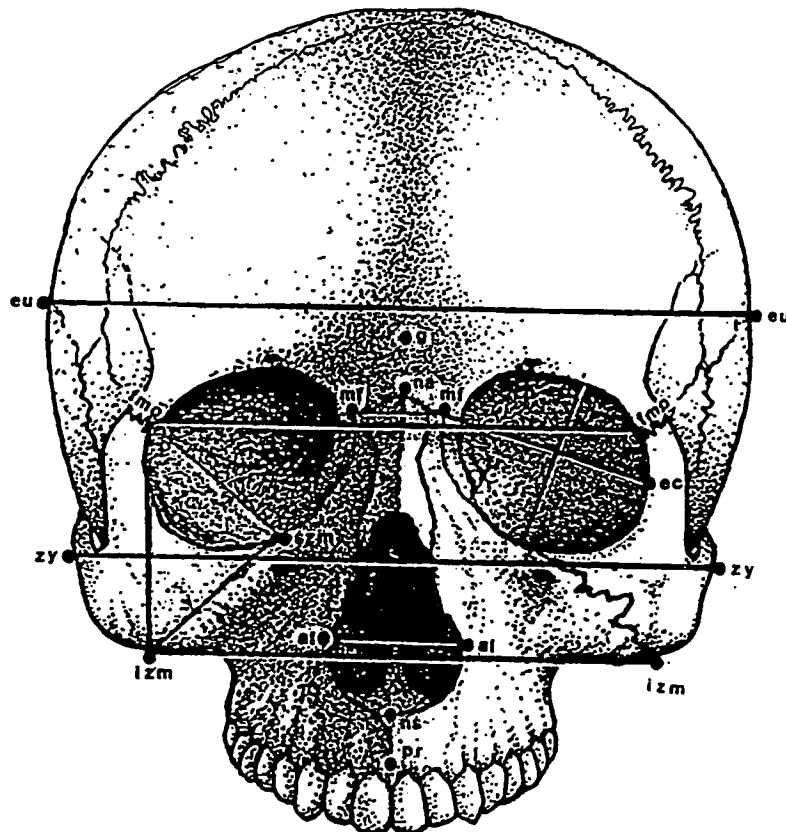
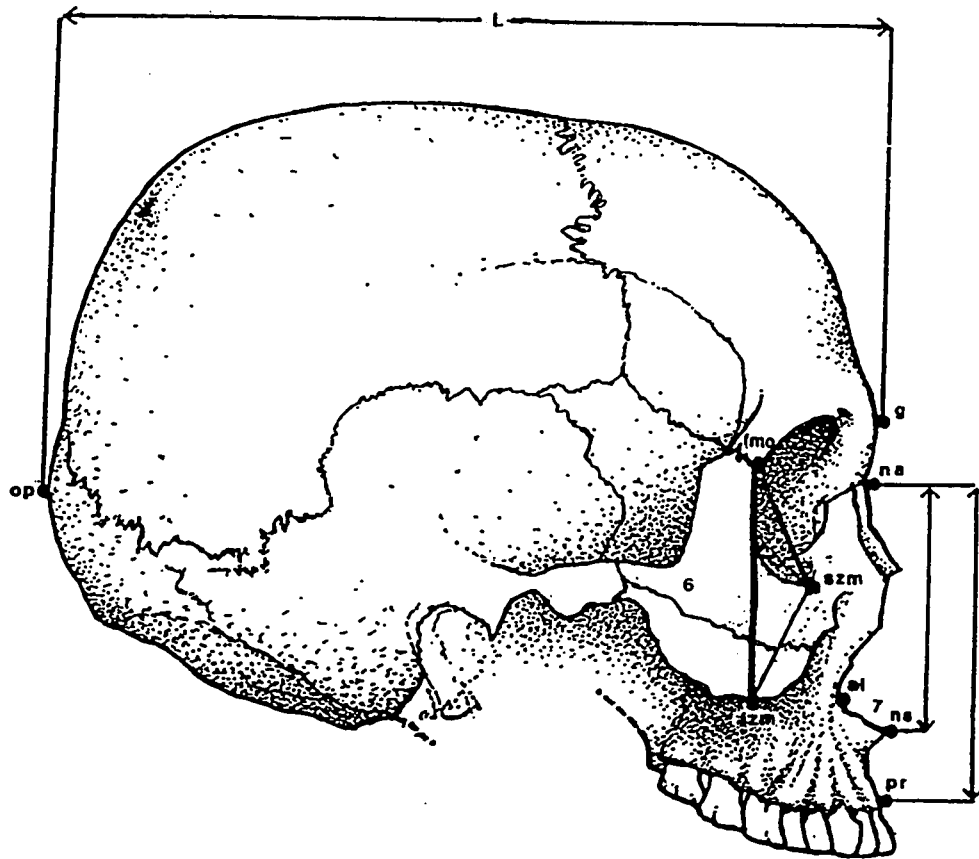


Figure 9. Morphological Landmarks for the Craniofacial Metric Traits (Frontal View)



6 Os japonica

7 Subnasal

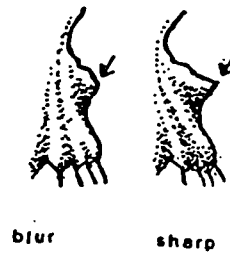


Figure 10. Morphological Landmarks for the Craniofacial Metric and Discrete Traits (Lateral View)

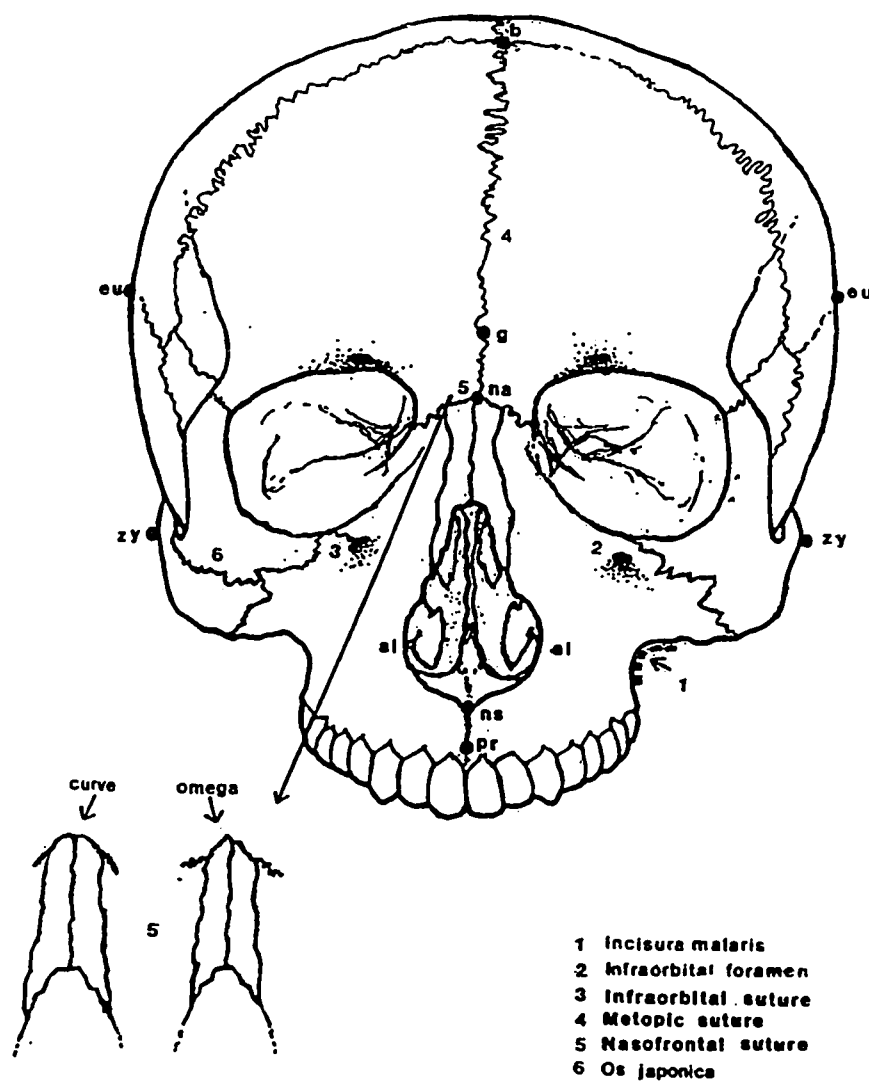


Figure 11. Morphological Landmarks for the Craniofacial Discrete Traits (Frontal View)

APPENDIX II
DESCRIPTION AND GRAPHIC PRESENTATION OF BOXPLOTS
USED IN MALE AND FEMALE COMPARISONS
OF EACH POPULATION GROUP

The boxplot is a form of graphical summary. The graph presents a box as the middle range or middle half of the data batch. The lines that mark the two ends of the box are called “hinges.” The distance from the upper hinge (sometimes called the upper fourth) to the lower hinge (or lower fourth) is called the “hinge spread or H-spread.” The crossbar inside the box represents the value of the median. The median divides the data into two halves, and each hinge marks half of each half. The hinges can be pinpointed by using the depth of the hinge or $d(H)$,

$$d(H) = ([d(M)] + 1)/2$$

where

$$d(M) \text{ or depth of median} = (n+1)/2 \text{ or } (n+1)/2 - 1/2$$

(Velleman and Hoaglin 1981:42–43).

There are two types of outliers, i.e., “outlier” and “far outlier”

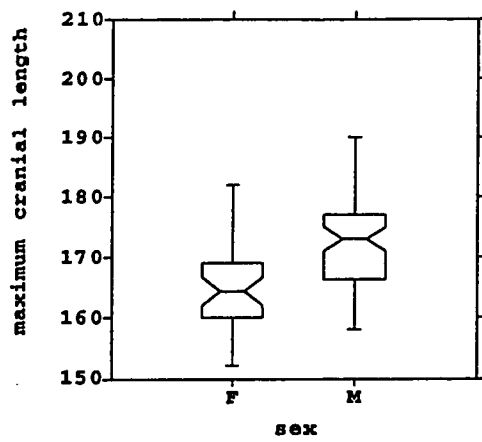
which are marked as an asterisk and an open circle, respectively, in SYSTAT (Wilkinson 1989).

Another type of boxplot is called the notched boxplot. The notched boxplots are used for the purpose of comparison between the boxes. The notches define an interval around the median which can indicate that the two population medians are significantly different at about 5% level if the notched areas of the two boxes do not overlap. The notches are symmetrically placed at

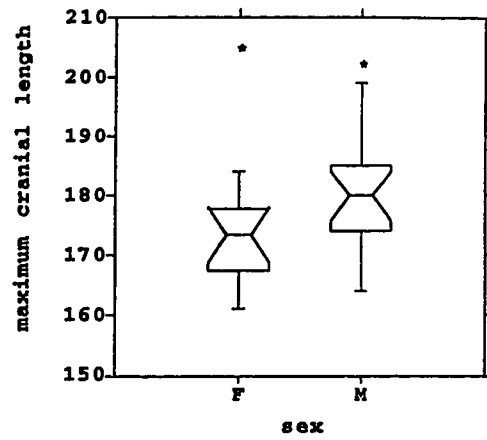
$$\text{median} \pm 1.58 \times (\text{H-spread})/\sqrt{n}$$

(Velleman and Hoaglin 1981:74).

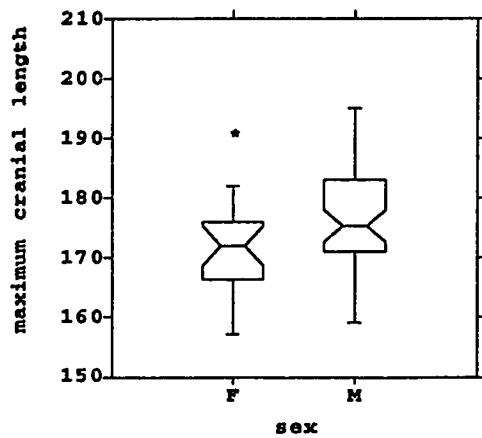
Therefore, any notched boxplots which exhibit the flip over at either end indicate that the hinge on that end lies within the notched area.



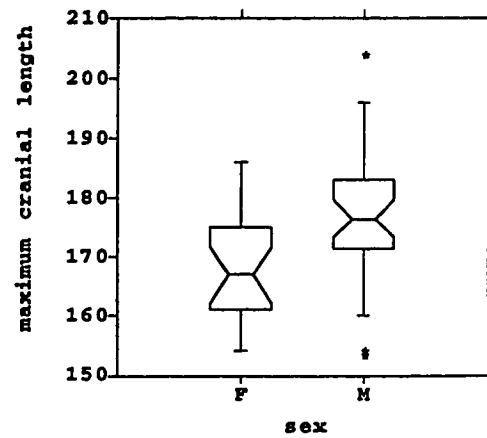
(a) Modern Thai



(b) Archaeological Thai

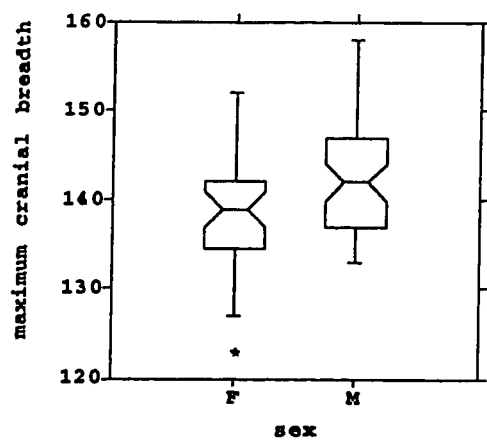


(c) Modern Chinese

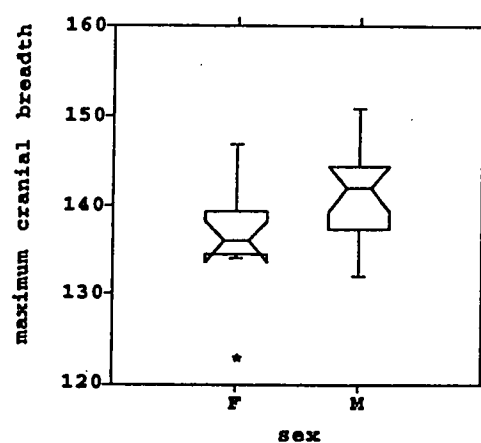


(d) Archaeological Chinese

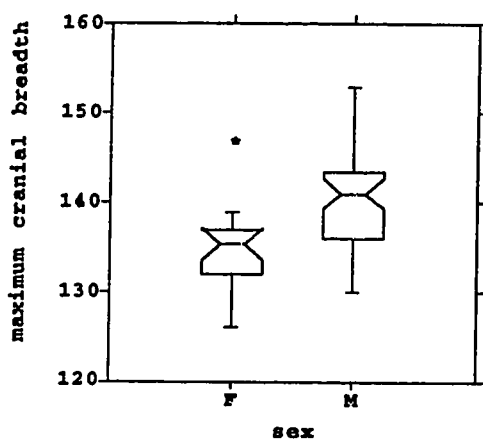
Figure 12. Boxplot Comparisons of Maximum Cranial Length (g-op) for Male and Female of Each Population Group



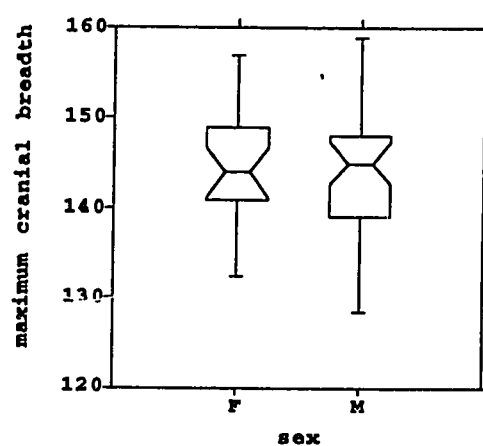
(a) Modern Thai



(b) Archaeological Thai

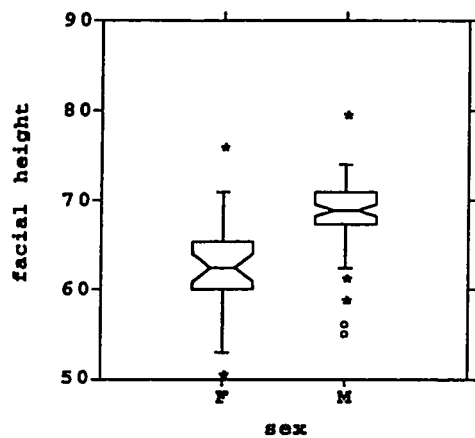


(c) Modern Chinese

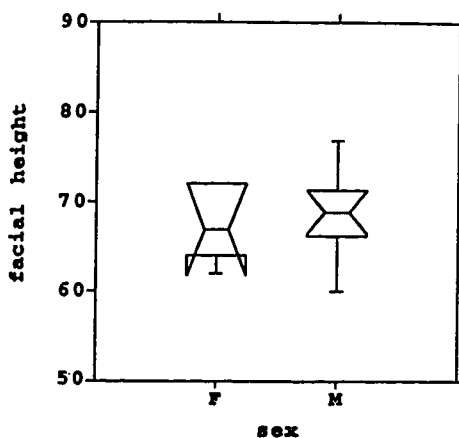


(d) Archaeological Chinese

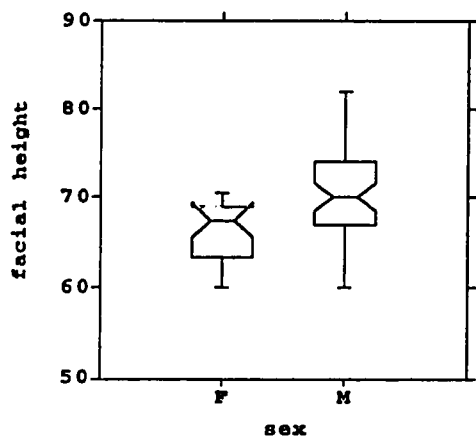
Figure 13. Boxplot Comparisons of Maximum Cranial Breadth (eu-eu) for Male and Female of Each Population Group



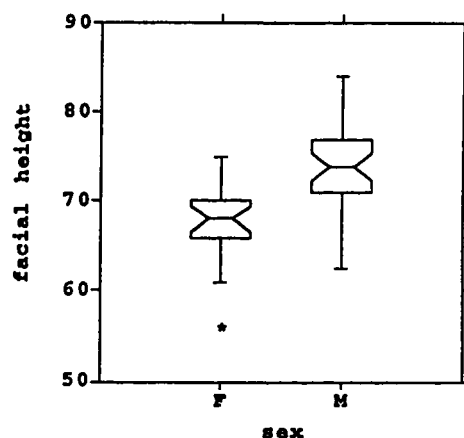
(a) Modern Thai



(b) Archaeological Thai

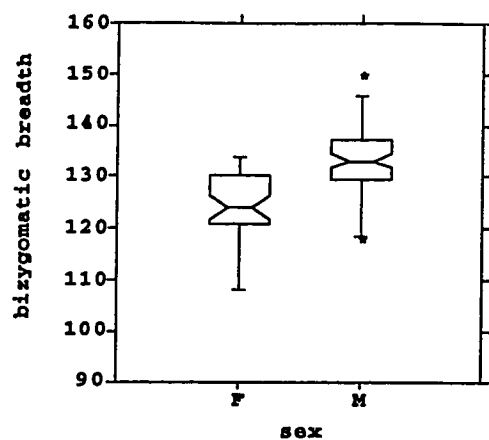


(c) Modern Chinese

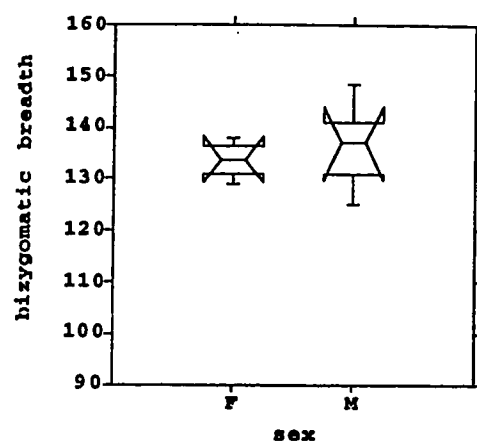


(d) Archaeological Chinese

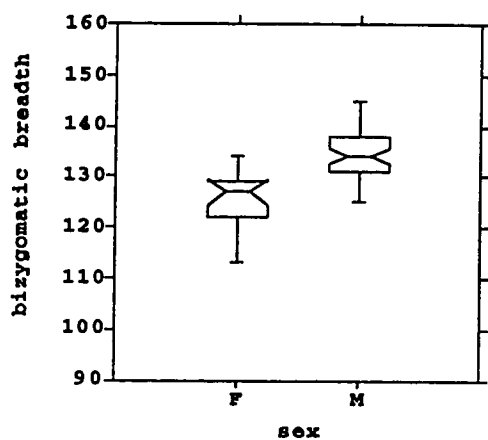
Figure 14. Boxplot Comparisons of Facial Height (na-pr) for Male and Female of Each Population Group



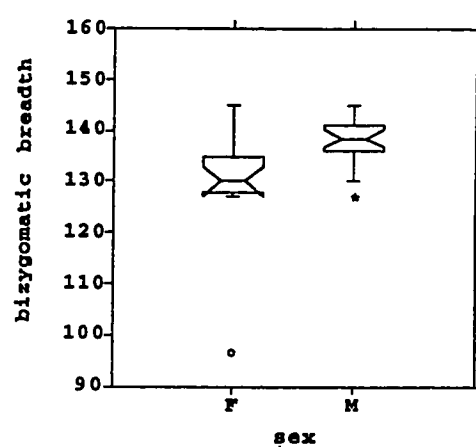
(a) Modern Thai



(b) Archaeological Thai

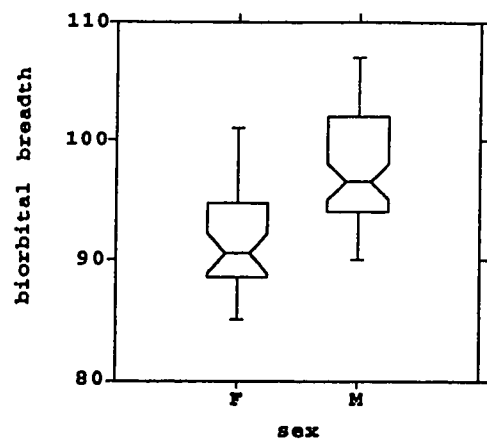


(c) Modern Chinese

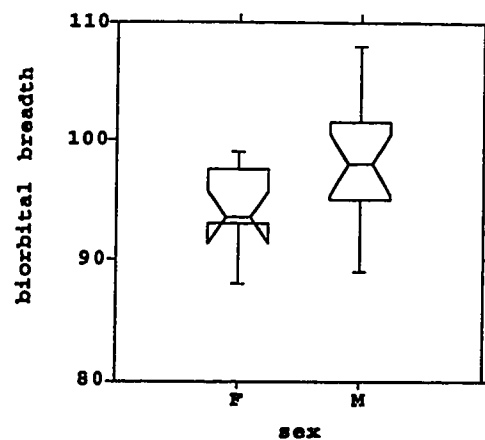


(d) Archaeological Chinese

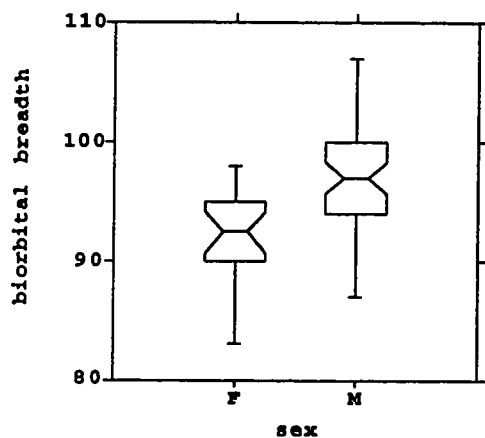
Figure 15. Boxplot Comparisons of Bizygomatic Breadth (zy-zy) for Male and Female of Each Population Group



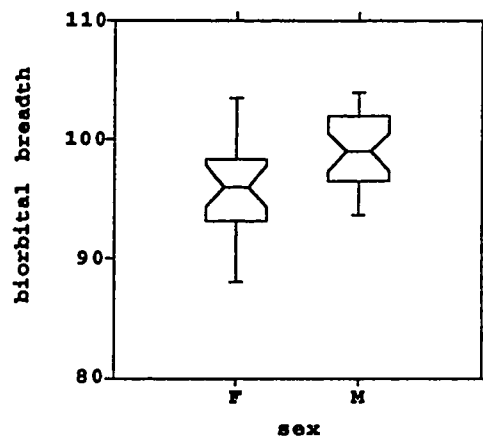
(a) Modern Thai



(b) Archaeological Thai

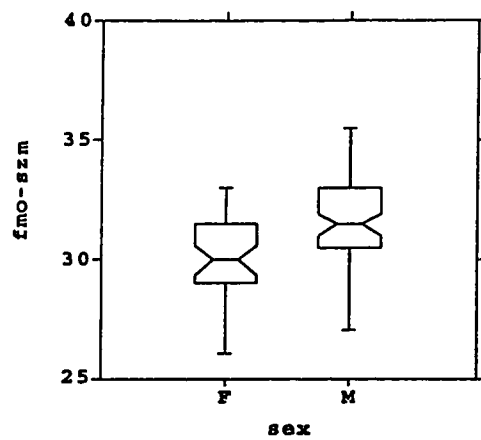


(c) Modern Chinese

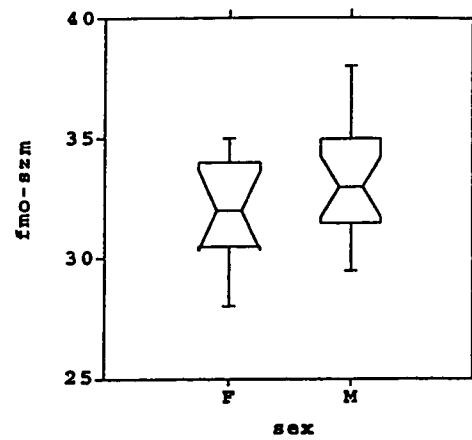


(d) Archaeological Chinese

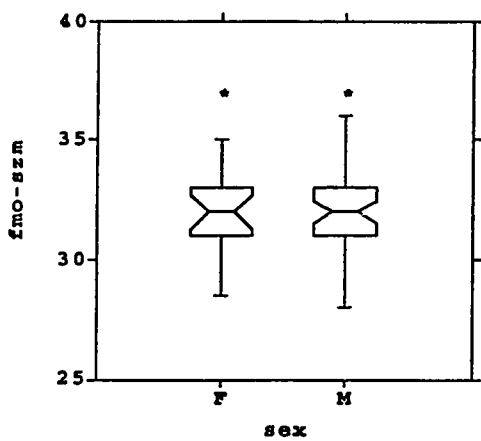
Figure 16. Boxplot Comparisons of Biorbital Breadth (fmo-fmo) for Male and Female of Each Population Group



(a) Modern Thai

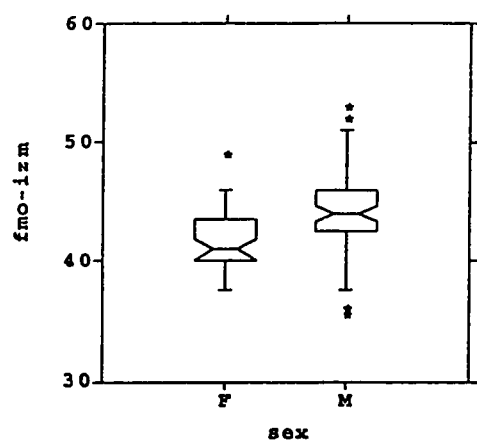


(b) Archaeological Thai

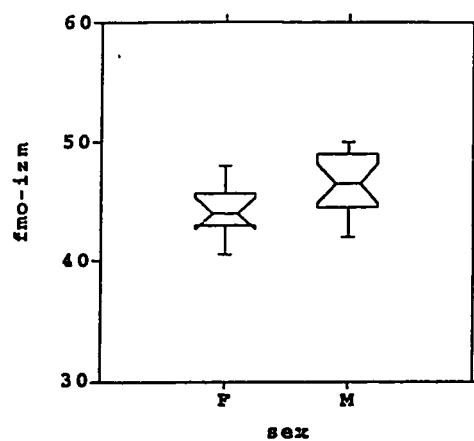


(c) Modern Chinese

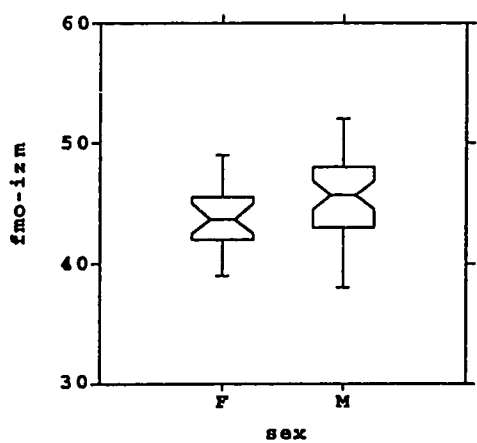
Figure 17. Boxplot Comparisons of Frontomale Orbitale to Superior Zygomaxillare (fmo-szm) for Male and Female of Each Population Group



(a) Modern Thai

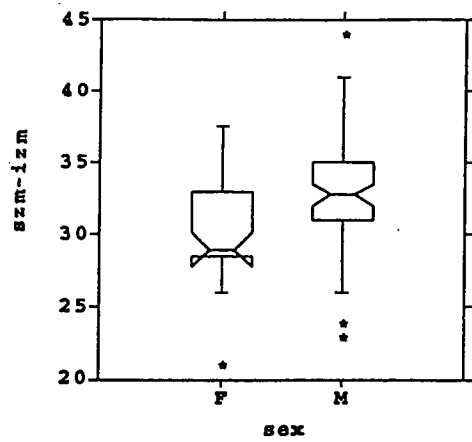


(b) Archaeological Thai

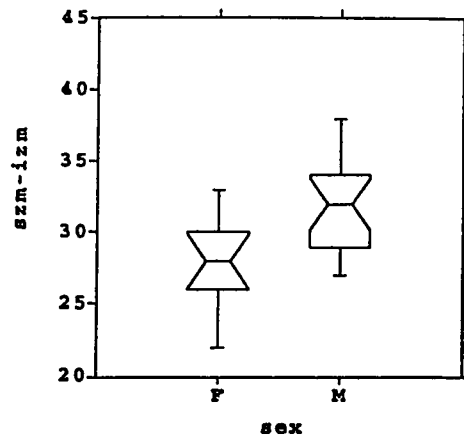


(c) Modern Chinese

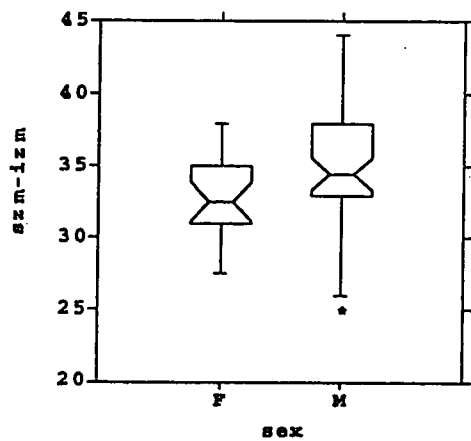
Figure 18. Boxplot Comparisons of Frontomale Orbitale to Inferior Zygomaxillare (fmo-izm) for Male and Female of Each Population Group



(a) Modern Thai

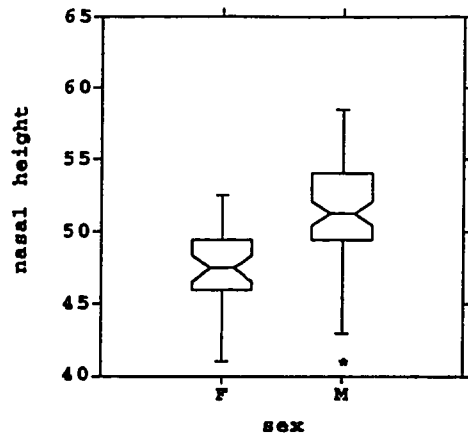


(b) Archaeological Thai

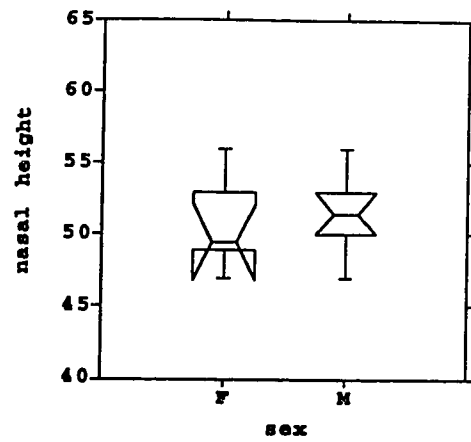


(c) Modern Chinese

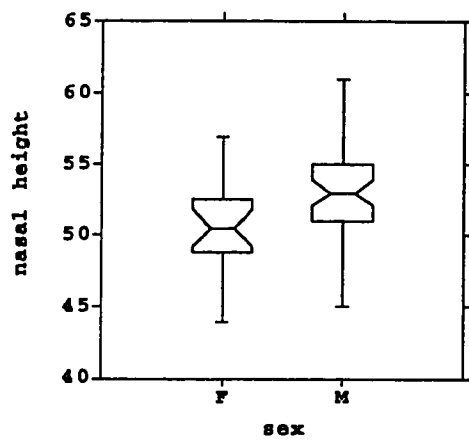
Figure 19. Boxplot Comparisons of Superior Zygomaxillare to Inferior Zygomaxillare (szm-izm) for Male and Female of Each Population Group



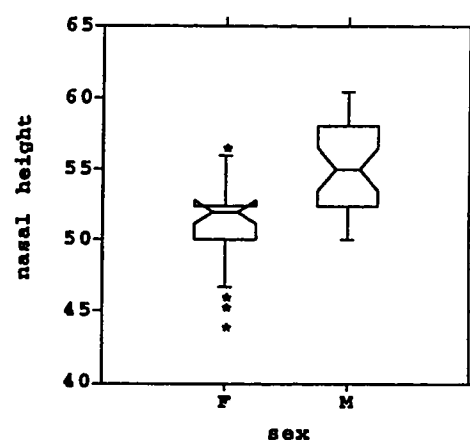
(a) Modern Thai



(b) Archaeological Thai

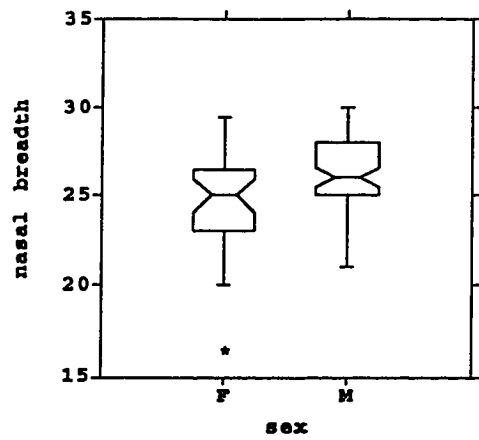


(c) Modern Chinese

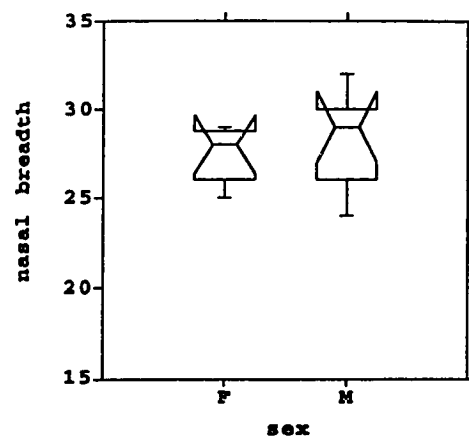


(d) Archaeological Chinese

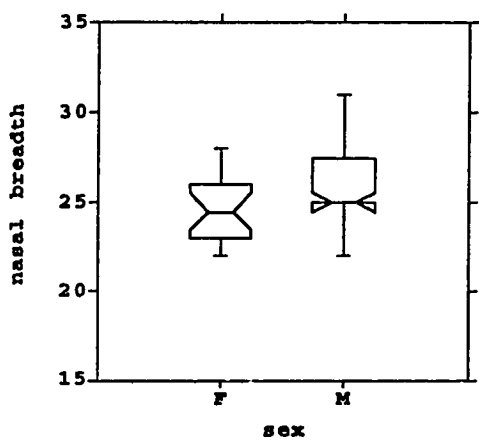
Figure 20. Boxplot Comparisons of Nasal Height (na-ns) for Male and Female of Each Population Group



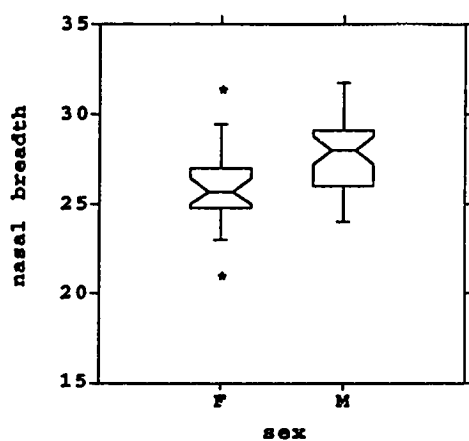
(a) Modern Thai



(b) Archaeological Thai

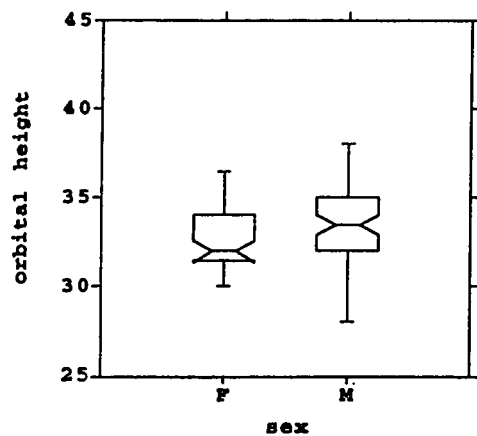


(c) Modern Chinese

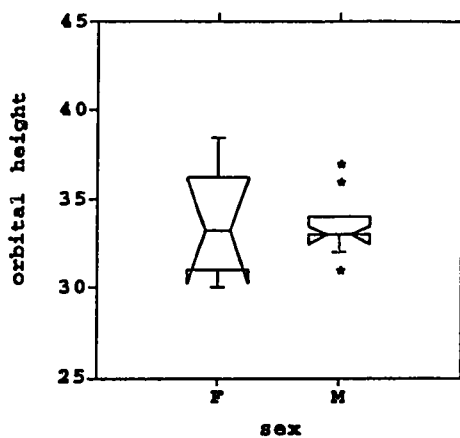


(d) Archaeological Chinese

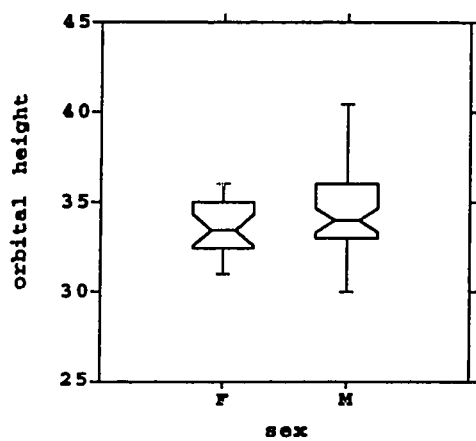
Figure 21. Boxplot Comparisons of Nasal Breadth (al-al) for Male and Female of Each Population Group



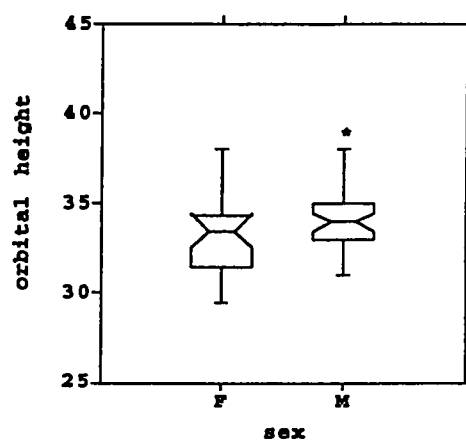
(a) Modern Thai



(b) Archaeological Thai

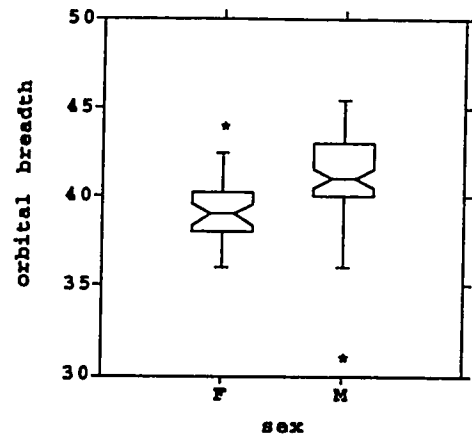


(c) Modern Chinese

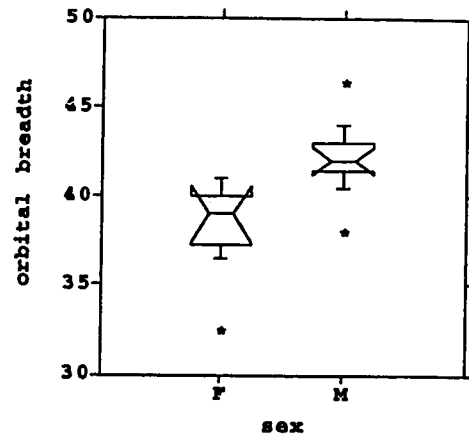


(d) Archaeological Chinese

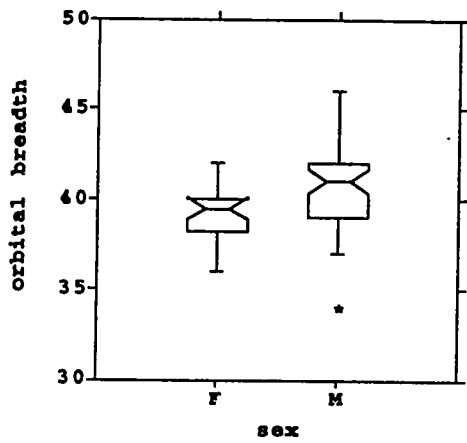
Figure 22. Boxplot Comparisons of Orbital Height (orb-h) for Male and Female of Each Population Group



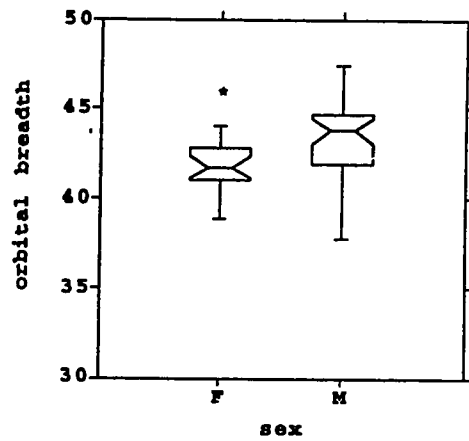
(a) Modern Thai



(b) Archaeological Thai

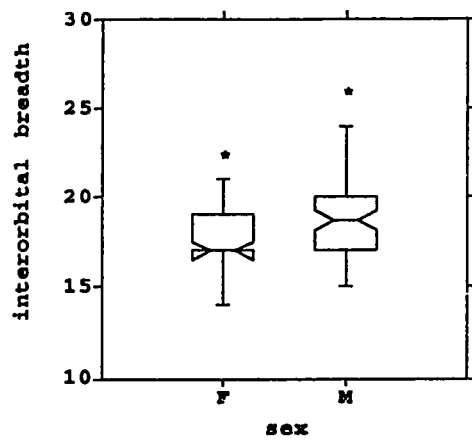


(c) Modern Chinese

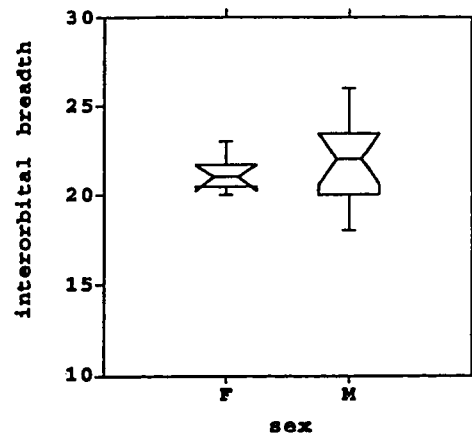


(d) Archaeological Chinese

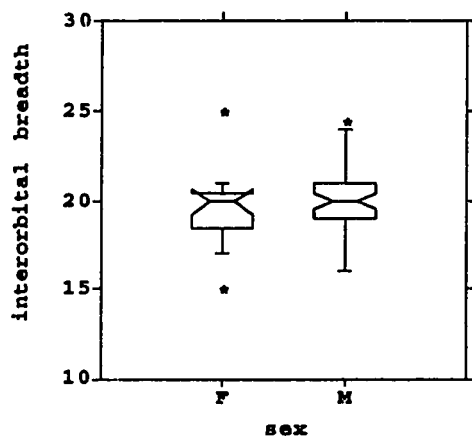
Figure 23. Boxplot Comparisons of Orbital Breadth (orb-b) for Male and Female of Each Population Group



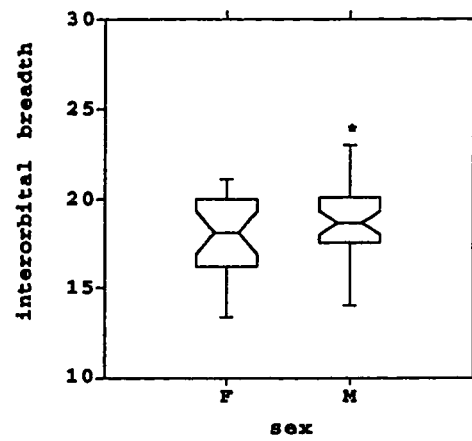
(a) Modern Thai



(b) Archaeological Thai

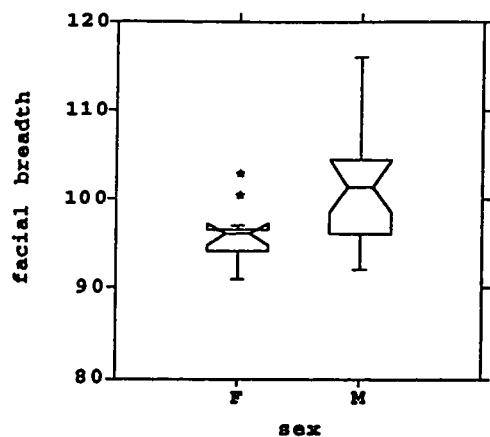


(c) Modern Chinese

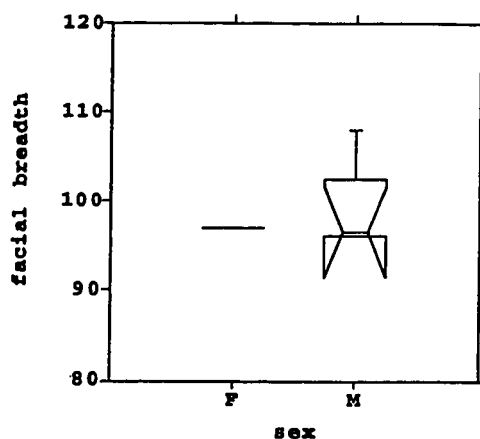


(d) Archaeological Chinese

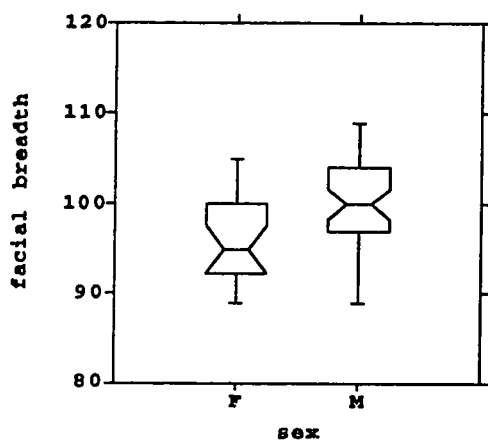
Figure 24. Boxplot Comparisons of Interorbital Breadth (int-or) for Male and Female of Each Population Group



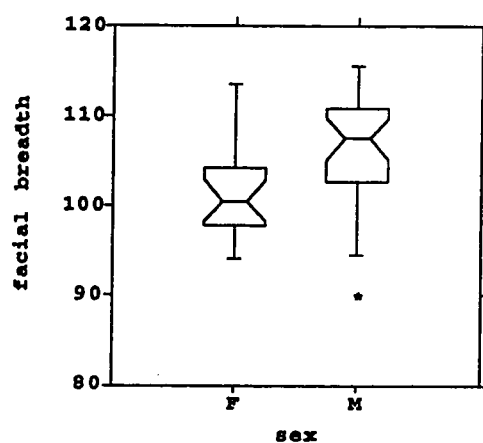
(a) Modern Thai



(b) Archaeological Thai



(c) Modern Chinese



(d) Archaeological Chinese

Figure 25. Boxplot Comparisons of Facial Breadth (max-max) for Male and Female of Each Population Group

APPENDIX III

GRAPHIC PRESENTATION OF PRINCIPAL COMPONENTS ANALYSES

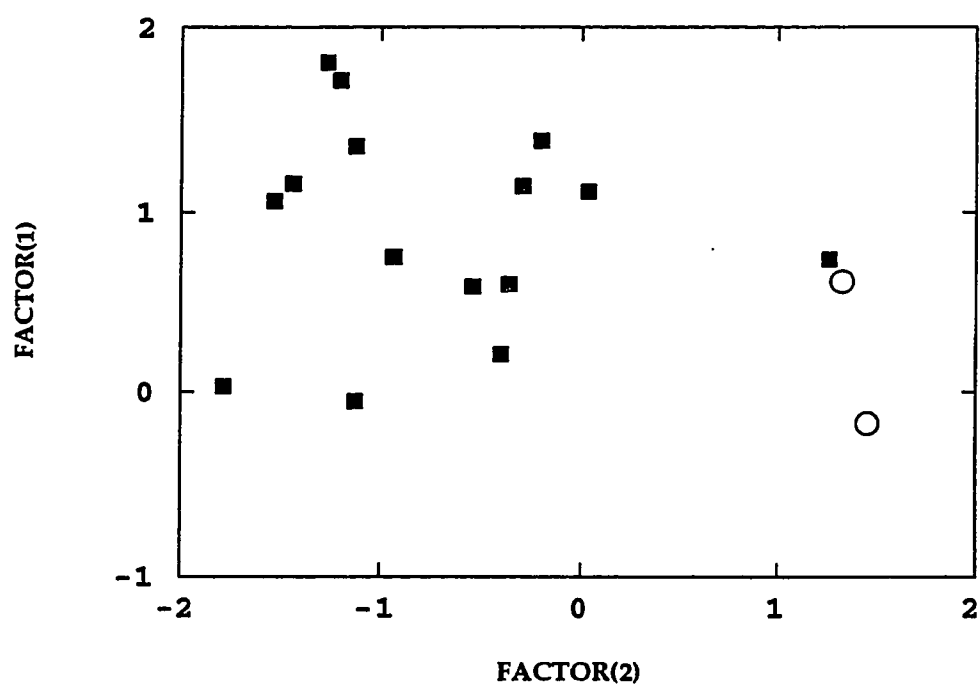


Figure 26. First and Second Component Scores Plots for Male Archaeological Thai and Chinese Groups

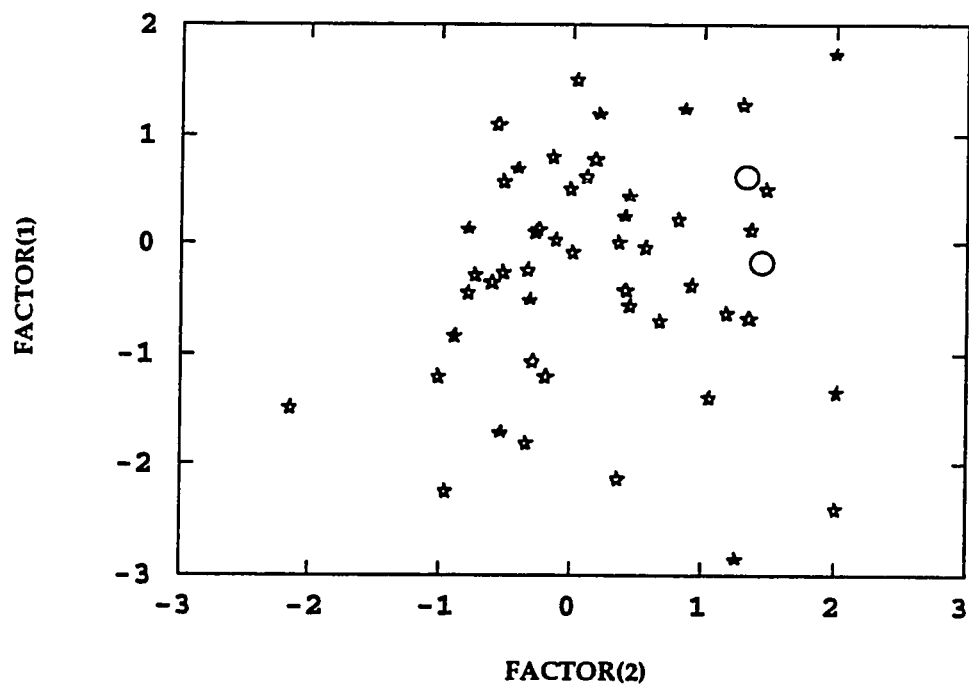


Figure 27. First and Second Component Scores Plots for Male Archaeological and Modern Thai Groups

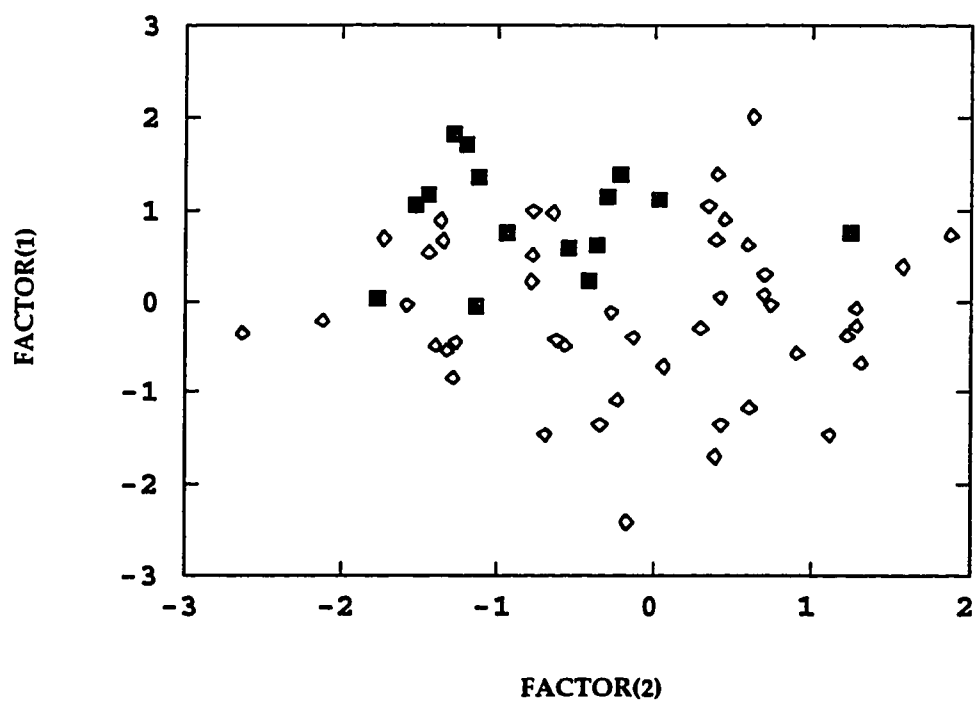


Figure 28. First and Second Component Scores Plots for Male Archaeological and Modern Chinese Groups

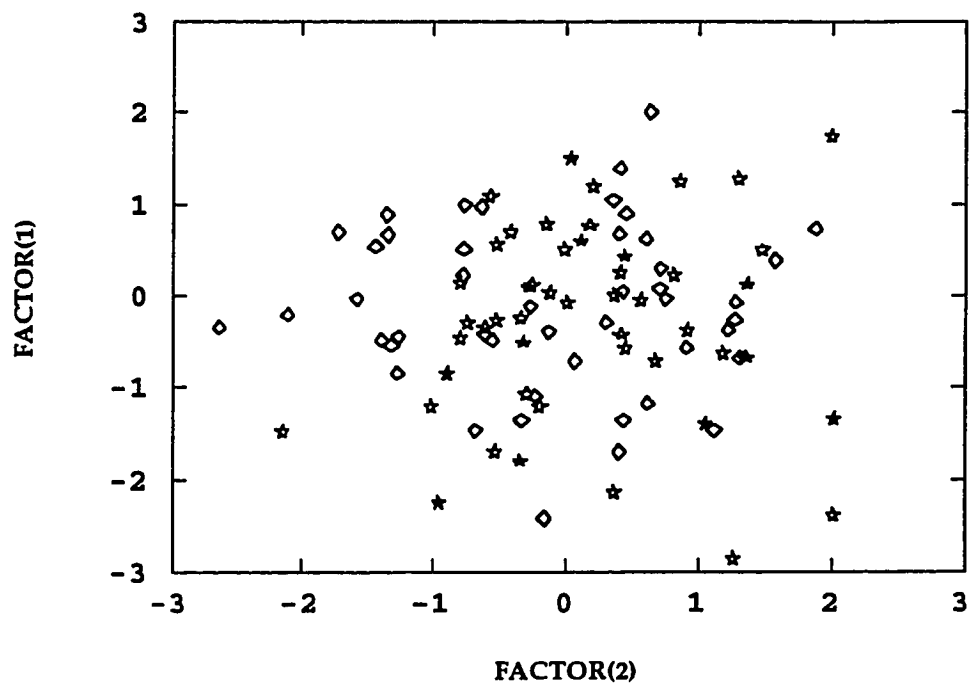


Figure 29. First and Second Component Scores Plots for Male Modern Thai and Chinese Groups

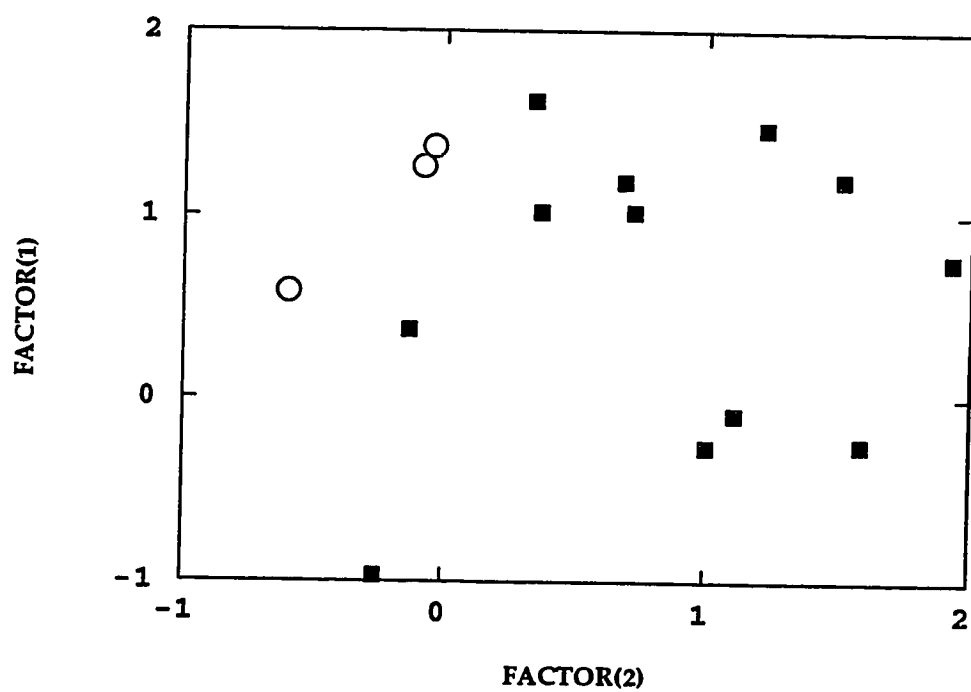


Figure 30. First and Second Component Scores Plots for Female Archaeological Thai and Chinese Groups

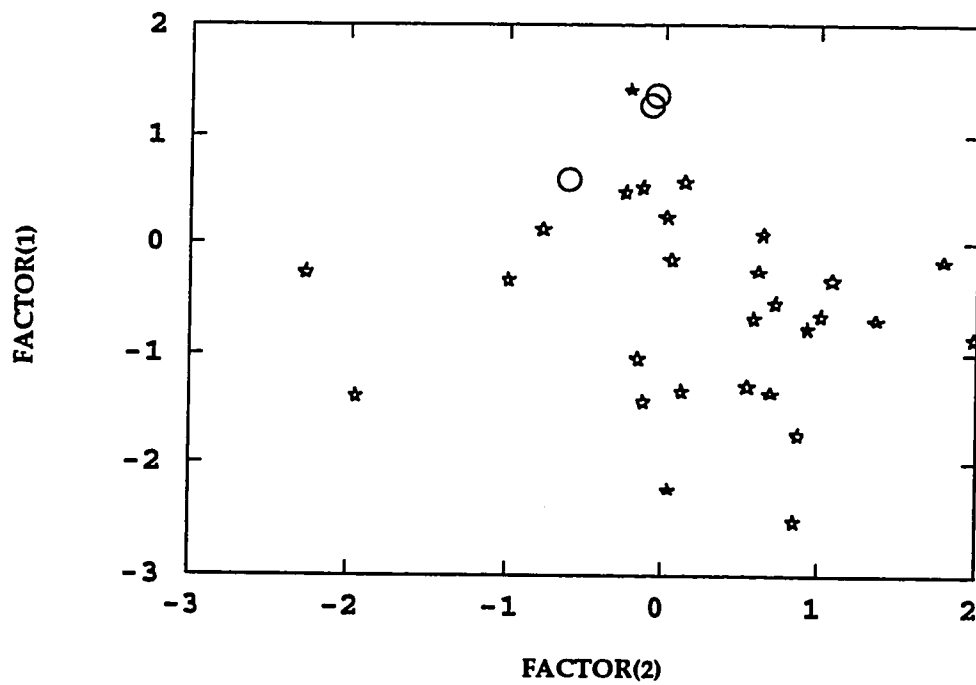


Figure 31. First and Second Component Scores Plots for Female Archaeological and Modern Thai Groups

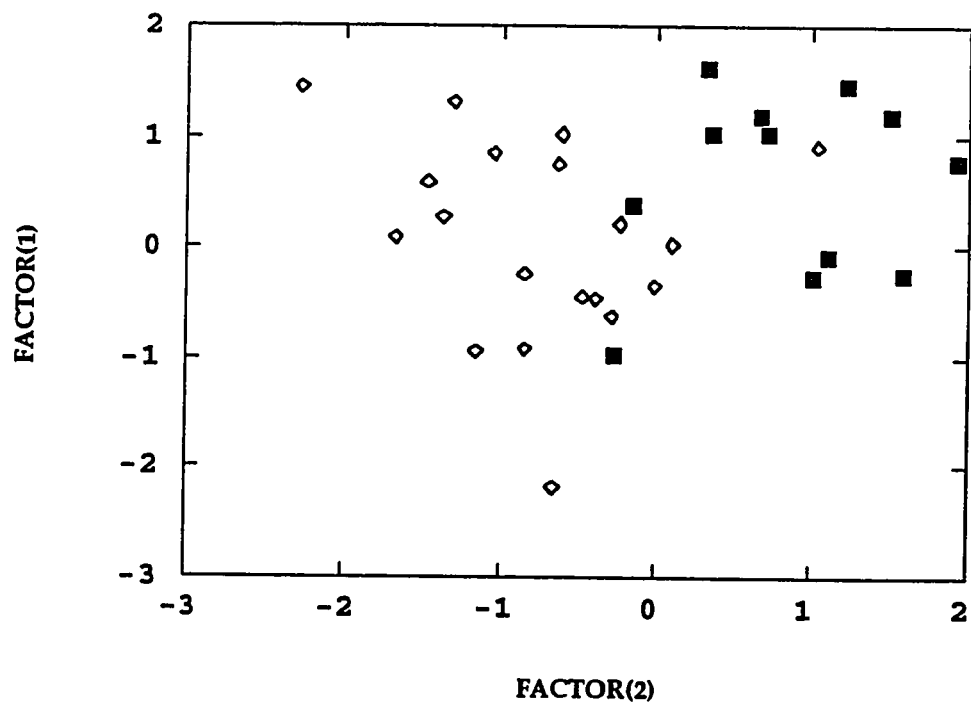


Figure 32. First and Second Component Scores Plots for Female Archaeological and Modern Chinese Groups

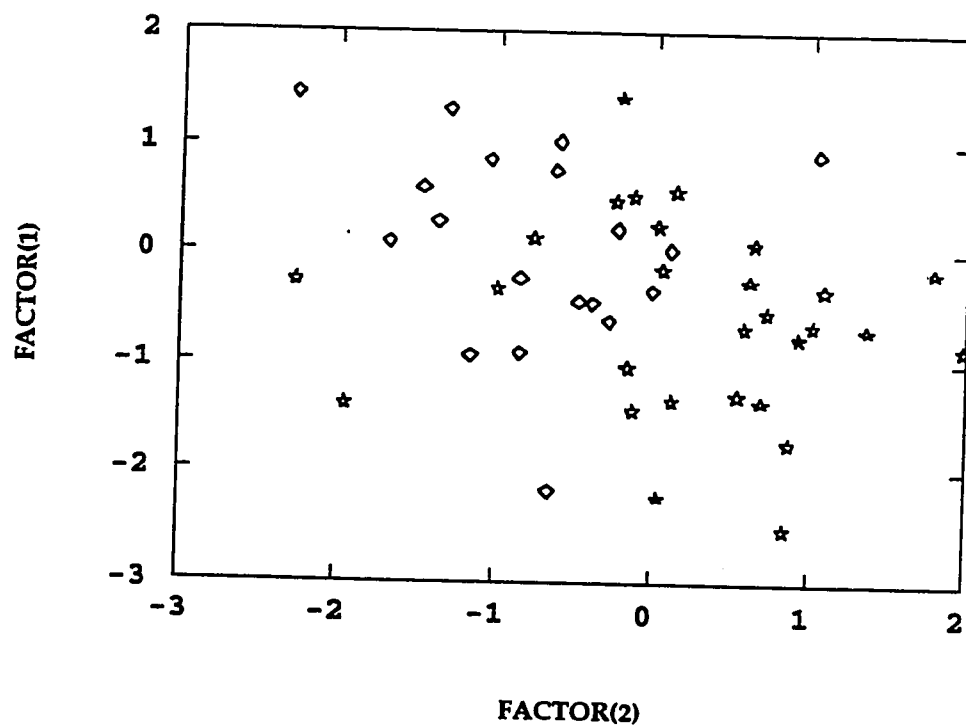


Figure 33. First and Second Component Scores Plots for Female Modern Thai and Chinese Groups

VITA

Supaporn Nakbunlung was born on March 12, 1955, in Phuket, southern Thailand. She grew up in Bangkok and graduated from Benjamaracharai High School in 1972. Four years later, she received a second class honor B.A. from the Faculty of Archaeology, Silpakorn University. In 1976, she accepted a teaching position at the Department of Sociology and Anthropology, Faculty of Social Sciences, Chiang Mai University.

In 1979, she started her graduate study at Northern Illinois University in DeKalb under the exchange program between Northern Illinois and Chiang Mai Universities. She majored in physical anthropology because, at the time, there were no physical anthropologists in Thailand. In 1982, she received an M.A. and went back to her teaching career. Participating in paleoanthropological research project inspired her to come back to further her study in paleoanthropology at the University of Illinois at Urbana-Champaign in 1989. At UIUC she has held appointments as a research assistant and as a teaching assistant. Several grants have been awarded for her dissertation research project. She was co-author for chapters in Thai monographs and for articles in international professional journals. Her future plan is to return to serve her country at Chiang Mai University, Thailand.