This is to certify that the

thesis entitled

"A Test of Non-Metric Ancestry Determination in Forensic Anthropology: Should the current categorization of individuals of European descent be reconsidered?"

presented by

Valerie N. Yavornitzky

has been accepted towards fulfillment of the requirements for

M.A. degree in Anthropology

Dr. Norman J. Sauer

Major professor

Date November 8, 2002

A TEST OF NON-METRIC ANCESTRY DETERMINATION IN FORENSIC ANTHROPOLOGY: SHOULD THE CURRENT CATEGORIZATION OF INDIVIDUALS OF EUROPEAN DESCENT BE RECONSIDERED?

By

Valerie Nicole Yavornitzky

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF ARTS

Department of Anthropology

2002

ABSTRACT

A TEST OF NON-METRIC ANCESTRY DETERMINATION IN FORENSIC ANTHROPOLOGY: SHOULD THE CURRENT CATEGORIZATION OF INDIVIDUALS OF EUROPEAN DESCENT BE RECONSIDERED?

By

Valerie N. Yavornitzky

In the field of forensic anthropology, analyses of non-metric skeletal traits play a vital role in the determination of ancestry from the human skull. However, there remains a need for more data and research on the heritability of specific non-metric skeletal traits and their distribution in worldwide populations to fully support their use in the determination of ancestry or "race" from human skeletal remains. Current ancestral categories used by forensic anthropologists to define people are too broad and are primarily limited to European, African, and Asian. In this study, I test a portion of the trait list for the "American Caucasoid" category devised by Rhine in his widely-used study on the ancestral classification of non-metric traits, "Non-Metric Skull Racing" (Rhine, 1990), on a series of crania from the Mütter Museum of the College of Physicians of Philadelphia. This study aims to statistically evaluate whether the broad category of European ancestry can be narrowed so as to account for the variation present in European subpopulations. It is my goal to propose a more geographically specific classification system for determining ancestry in forensic anthropology from non-metric skeletal traits.

TABLE OF CONTENTS

CONTINUED

LIST OF TABLES

APPENDICES TABLE KEY

Symbol	**Meaning**
*	Statistical results are significantly different than expected outcome at the 95% confidence level.
+	Indicates that Mütter sample data is statistically different than Rhine's (1990) dataset, however results in table correlate with what Rhine (1990:Table 3) lists as expected per ethnic group.
F	Fisher's Exact (2-Sided) Test of Significance Replaces Chi-Square Test
V	Violates Chi-Square assumption of expected count of at least five; results remain significant

Chapter 1

STATEMENT OF PROBLEM

Introduction

"'Races' have no more or less reality than 'chairs' since both are human informational constructs which will linguistically and conceptually persist only as long as they serve the purposes of their users" (Kelso, 1970:94). Despite the acknowledgement by most physical anthropologists that typological races are defunct as a biological concept, forensic anthropologists contend that socially-defined races may still be of practical use to the field (Gill & Rhine, 1990; Sauer, 1992). Forensic anthropologists continue to assign race or ancestry based on specific characteristics of the human skeleton to unidentified skeletal remains. While this practice seemingly contradicts the idea that discrete biological races do not exist, forensic anthropologists insist that the determination of race or ancestry from skeletal remains for identification purposes is both useful and necessary (Gill, 1998; Brace, 1995; Kennedy, 1995; Sauer, 1992; Gill, 1986). Because society continues to group people into racial or ancestral categories in census data, polls, research studies, and medico-legal documents, the social concept of race persists in modern societies (Gill, 1998; Brace, 1995; Kennedy, 1995; Sauer, 1992; Gill, 1986). Although forensic anthropologists may be perpetuating "a myth that human races are natural entities within our species" by employing ancestry determination methods (Kennedy,1995:798), forensic anthropologists use this social reality to advance their goal: the identification of unknown human remains.

The job of the forensic anthropologist is to ascertain from human remains sex, age-at-death, ancestry, stature, body form, pathology, antemortem and postmortem trauma, occupational stresses, and any information that may help to understand the manner of or time since death. The purpose of creating this biological profile is to aid in the identification of an individual from his or her remains. Often the ability to identify an individual hinges on the ability to communicate with law enforcement or the general public. It is for this reason that racial or ancestral categories are used in the biological description of human remains. Because American culture continues to identify and categorize people by race as based on the social constructs of the concept, it is often helpful for ancestry information to be provided in the biological description of an unidentified individual, assuming that such information can be ascertained from the remains. The more information forensic anthropologists can provide law enforcement regarding the appearance of an individual during life, the better the attempt to identify missing individuals will be.

Statement of Problem

While there is no genetic evidence to support the existence of various subspecies in Homo sapiens, there is data to support that certain skeletal traits are particular to given geographic regions (Brace, 1995; Sauer, 1992; Kennedy, 1995). However, what delineates a geographic region and the skeletal traits specific to it have neither been clearly defined nor exhaustively explored. Non-metric analyses (Gill and Rhine, 1990) and metric analyses (Giles and Elliot, 1962; Howells, 1995) have been used to determine ancestry from the human skeleton, but currently used methods need to be further researched and the broadly defined categories used to classify ancestry with non-metric traits – European, African and Asian – should be reevaluated (Brues, 1990; Rhine, 1990).

Because there is a significant amount of non-metric and metric human skeletal variation just within the United States, a problem compounded by gene flow and immigration, classifying individuals into the broadly defined ancestry categories used in the U.S. – European, African, and Asian – has become impractical. Most people in the U.S. and much of the rest of the world have more than one ancestral background, and many of these people would classify themselves outside of these three major ancestral categories. Further, the increasing involvement of forensic anthropologists abroad necessitates an understanding of human variation in other regions of the world (Worden, 1995; Simmons and Lagrou, 2001). Individuals within the United States that would be classified as "European" may, and most likely do, look different than people living in Europe. A better understanding of how human skeletal variation should be classified to best support the goal of forensic anthropology is necessary and justified (Ousley and Billeck, 2001; Kennedy, 1995).

The largest publication to report on the use of non-metric traits in the forensic identification of race, "Skeletal Attribution of Race" (Gill & Rhine, 1990) documents several studies that examine the validity of non-metric methods. These studies include a discussion of the distribution of shovel-shaped incisors and of alveolar prognathism, the use of the visibility of the oval window through the external auditory meatus, the inversion of the lower border of the mandible, and of a small study examining forty-five non-metric traits across four ancestral groups (Hinkes, 1990; Brooks et. al., 1990; Napoli & Birkby, 1990; Angel & Kelley, 1990; Rhine, 1990). Of these studies, the latter, "Non-metric skull racing", provides a list of non-metric traits currently used in forensic anthropology laboratories to aid in the determination of ancestry as well as the data used in the original study (Rhine, 1990). Although Rhine's (1990) study "Non-metric skull

skull racing" provides a fairly exhaustive list of non-metric traits considered by the Mountain, Desert, and Coastal Forensic Anthropologists membership to be of the most value in the determination of "race" from the human skull, the small sample size (Total N=87), the use of casts to represent approximately 1/3 of the "Black" sample, and the use of prehistoric Native Americans used in the study brings into question the accuracy of the study's conclusions (Rhine, 1990:10-12). While previously published studies have discussed the use of non-metric skeletal traits in the evaluation of "race" or ancestry, none take a sampling of several ancestral groups from within the United States and compare the frequency of forty-five trait occurrences across the groups as does Rhine (1990) (Hooton, 1920). Additionally, Rhine's (1990) work aims to examine the validity of the method not to determine biological distance between groups or the heritability of traits as do many other anthropological studies using non-metric traits as part of their analyses (Ullinger, 2002; Praymak et. al., 2001; Lane, 1978; Saunders & Popovich, 1978; Ossenberg, 1977). For these reasons, I have chosen to compare my data to Rhine's (1990) study and further the examination of the methodology used to determine ancestry from human skeletal remains.

I intend to re-examine the ancestry category "European" using non-metric data collected on 122 male skulls from the Hyrtl Skull Collection, a collection of 139 skulls primarily from Central and Eastern Europe located at the Mütter Museum in Philadelphia, Pennsylvania. This study will compare the frequencies of nineteen non-metric traits evaluated from the Hyrtl sample to Rhine's (1990) "Anglo" sample (n=53), "Hispanic" sample (n=15), "Indian" sample (n=12), and "Black" sample (n=7) from the Maxwell Museum's Skeletal Collection (Rhine, 1990:9). The non-metric traits used to evaluate the from “Non-Metric Skull Racing” (Rhine, 1990:10). Specific traits used in the Hyrtl skull study were selected for their ease to record, their tendency to be less subjective (reduction of inter-observer error), and their previously determined value in evaluating ancestry from the human skull.

Considering this, three questions are proposed of the collected data. From these questions, hypotheses to be tested are set forth.

Question 1: Are the current practices for the determination of “European” ancestry in forensic anthropology accurate? Does the Hyrtl skull data support the expected trait frequencies for “Caucasoids” in Rhine (1990) study?

The following two hypotheses will allow me to test the validity of Rhine’s “European“ ancestry category:

> <u>Null Hypothesis 1 - European Definition Hypothesis</u>: The non-metric data collected will demonstrate there to be no statistically significant difference in the distribution of discrete trait frequencies between the Hyrtl Skull Sample and Rhine’s (1990) “Anglo” sample from the Maxwell Museum Collection.
>
> <u>Null Hypothesis 2 - European Distinction Hypothesis</u>: The non-metric data collected will demonstrate there to be no statistically significant differences in the distribution of discrete trait frequencies among the Hyrtl Skull Sample and any of Rhine’s (1990) three non-European samples from the Maxwell Museum Collection.

If the <u>European Definition Hypothesis</u> is rejected then a successful argument can be made for changing the current description of Europeans in the non-metric cranial trait literature. If the <u>European Distinction Hypothesis</u> is rejected then an argument can be made for maintaining the current non-metric cranial trait distinction among European people and people of a different ancestral lineage.

people and people of a different ancestral lineage.

Question 2: Does the data indicate that certain traits can be distinguished among regional or ethnolinguistic groups located within Europe? Can bivariate statistical tests demonstrate statistical differences among specific traits among such groups? The Hyrtl collection will be sorted in two fashions: (1) geographically by region according to the Federation of East European Family History Societies (2001) electronic maps; and (2) ethnolinguistically according to the "Historical Atlas of East Central Europe" (1993).

> Null Hypothesis 3 - European Trait Consistency Hypothesis: Traits in the dataset will not be statistically different among the created subgroups.

If the European Trait Consistency Hypothesis is rejected, this will indicate that certain traits are better at differentiating the subgroups from one another and are of more value in the forensic determination of ancestry from the human skull in this collection. Further, the statistical results will show which method of grouping the subjects is most reliable. This will explicate which of the two grouping methods - geographic or ethnolinguistic - provides a more direct correlation with distinguishing skeletal features.

Question 3: The third objective of this study is to discover whether ancestry can be more specifically determined from non-metric traits of the human skull. Does the data support the narrowing of the currently used ancestry classification system?

Considering this, the following null hypothesis is proposed:

> Null Hypothesis 4 - European Regions Hypothesis: The means of the data will not be statistically different among regional/ethnolinguistic groups within the Hyrtl sample, supporting the notion that there is no statistically significant variation in the distribution of non-metric or metric traits among people with European ancestry.

The examination of this intrapopulational variation is to determine if ancestry categories can be made more geographically specific, because the current classification system - European, African and Asian - is limited in its use and oftentimes inaccurate. If it can be demonstrated that certain non-metric traits, currently used to predict European ancestry, have statistically different means among regional groups of Europeans, then Null Hypothesis 4 will be rejected.

While this dataset does not incorporate individuals from the whole of Europe, rather only the Central/Eastern European region, it does provide an opportunity to examine differences existing among some European peoples. While the multivariate statistics may not demonstrate as large of differences among the subgroups as they might if more individuals within the dataset originated in other parts of Europe, this dataset does have documented place of birth, which makes this skeletal collection a rarity and of great value to physical anthropological research. It is anticipated that even within this small European region, statistically significant differences will exist for specific traits among subgroups.

Anticipated Results and Contribution to Anthropology

Previous studies on non-metric craniofacial and dental morphology have failed to determine where the geographic lines of distinction lie for craniofacial and dental morphology. This is to say that no study has demonstrated craniofacial and dental traits to be solely specific to the area encompassing all of Europe and the Middle East. These geographic lines have been drawn to a certain degree arbitrarily, and it cannot be said that once these geographic boundaries have been crossed, morphology is distinctly different. Despite this, it has been proposed that individuals who appear to be "White" or generally of European descent tend to share suites of non-metric traits. If this is true, it is possible that the morphological variation of the skull will demonstrate suites of non-metric features to be specific to more narrowly defined geographic regions.

There has been no known test of Rhine's (1990) study that has examined the validity of his list for expected non-metric traits associated with "American Caucasoids" or individuals with European ancestry. Because Rhine's (1990) number of individuals for "Anglos" is only 53, less than half the size of the Hyrtl sample, it is possible that further research, including this study, will demonstrate there to be a different correlation between European ancestry and the given expected traits listed in Rhine (Rhine,1990:9-11).

In addition to such data-restricted reasons for the null hypotheses rejections, a few anthropologists have alluded to the fact that more geographically specific criteria for the determination of ancestry would be useful and is already being practiced. Kennedy (1995) notes that he is fairly confident of assigning ancestry based on the non-metric variation in individuals from the Indian subcontinent and Sri Lanka according to geographic sectors due to his extensive paleodemographic work in the area for many years. Further, he states that he would feel less confident doing the same with skeletons from another area of the world (Kennedy, 1995:799). Howells' (1995) metric analyses of crania have divided Europe into four ancestral categories: Norse, Zalavár, Berg, and Egypt. He has further divided other major geographic areas of the world into twenty-four distinct ancestral categories based on cranial metric variation (Howells, 1995:4-5). This study supports the view that geographically specific regional variation does exist for Homo sapiens, and that forensic anthropologists are justified in using more discriminating ancestry categories in the determination of ancestry from the human skull.

anthropology. While biological race has long been rejected as a valid concept by most physical anthropologists, the idea that variation in human morphology can tell anthropologists about past peoples is still vital. In forensic anthropology, applied methodology uses human variation to help graph the appearance of an individual during life from the morphology of their skeletal remains. The forensic application of non-metric methods for the determination of ancestry has not been adequately researched or discussed in the published literature. Rhine's (1990) study, "Non-Metric Skull Racing", only looks at a sample of 87 individuals and is one of the largest studies to date to examine a cross section of non-metric traits used in forensic anthropology (Rhine, 1990:9; Gill & Rhine, 1990:9-46). Research in the area of non-metric ancestry determination will strengthen forensic anthropologists' understanding of craniofacial and dental morphological variation as well as better their ability to identify individuals from human remains. Further research is necessary to assess the validity of the methods being used in forensic anthropology since human variation can best be understood by looking at larger samples and through the conducting of more studies. My study will aim to not only look at Rhine's classification of "Europeans" but also to assess whether the methodology being used is applicable to the Hyrtl Skull Sample. If Rhine's (1990) conclusions seem to be sample specific and not indicative of racial or ancestral features, forensic anthropologists should consider using methods other than non-metric traits in the determination of ancestry.

Chapter 2

THE USE AND VALUE OF NON-METRIC SKELETAL VARIANTS

The Definition of Non-metric Skeletal Variants

In the 1930s Hooton remarked, "morphological features which can be observed and described but cannot be measured are probably of greater anthropological significance than diameters and indices" (Brues, 1990:2). Over seventy years have passed since Hooton remarked on the importance of non-metric skeletal traits to physical anthropology, and non-metric analyses continue to play a vital role in the field today (Duray et al. 1999, Gill and Rhine 1990, Gill 1998 Hunley & Cabana 2001,Villmoare 2001, Durband et. al. 2002, Steininger 2002). Non-metric skeletal variants have been used in physical anthropology particularly to determine biological distance among populations of people (Ossenberg 1977, Molto 1979, Buikstra & Frankenberg 1990), ethnic or "racial" affinity (Rhine 1990, Gill and Rhine 1990, Gill 1998, Duray et. al. 1999), sex (Phenice 1969), age (Suchey et. al. 1986, Lovejoy et. al 1985), as well as identify markers of stress on the skeleton (Gruneberg 1952, Ossenberg, 1970). The value of non-metric traits in the determination of ancestral affinity and biological distance assessment has been argued as being greater than that of metric variables (Hooton 1930, Molto 1979, Brues 1990, Gill 1998). By discussing how non-metric skeletal variants have been used in science and their genetic basis, a better understanding of their value and practical use in physical anthropology can be gained.

Non-metric traits are discrete or most often quasi-continuous skeletal manifestations that cannot be measured and thus are scored. In the literature such traits have also been termed discrete traits, discreta, discontinuous traits, epigenetic traits, minor variants, and quasicontinuous traits (Buikstra & Ubelaker 1994: 85). Scoring for such traits may be on the presence/absence scale, however trends in the field of physical anthropology are leaning towards graded scoring forms that account for multiple types of a manifestation (e.g. nasal form, nasal aperture) or for the degree of variance or number of skeletal manifestations (e.g. base angle, nasal spine length; supraorbital foramen, extra ossicles, respectively) (Rhine 1990, Buikstra & Ubelaker 1994). This trend supports the idea purported by Grüneberg (1952) that non-metric skeletal variants are not discrete entities and that recording forms need to consider the quasi-continuous nature of such traits if possible.

Three major classes of quasi-continuous non-metric skeletal variants have been identified: foraminal, fusion, and hypostotic/hyperstotic. The first, foraminal, include the degree of closure and number of foramina present at a particular bony location. Buikstra and Ubelaker (1994) outline in Standards a number of varying human skeletal foramina of "primary importance" (Buikstra and Ubelaker, 1994: 87-93): suprascapular foramen, sternal foramen, jugular foramen, ethmoidal foramina, infraorbital foramina, foramen ovale, spinosum foramen, mental foramen, zygomatico-facial foramina, supratrochlear foramen, accessory lesser palatine foramen, accessory transverse foramina in C3-C7 vertebrae, parietal foramen, and the mastoid foramen.

The second class, fusion, is the degree to which two bones have fused at the sutural line. This class includes differential fusion of bones (e.g. metopic trace) but also deficiencies in bone formation (e.g. septal aperture of the humerus). The third class of traits, hypostotic/hyperstotic, refers to the underdevelopment or failure of ossification (hypostosis), or the over-development or abnormal formation of bone (hyperostosis).

This latter class is less specific in nature and generally includes the presence or absence of extra cranial ossicles. Buikstra & Ubelaker (1994) list the more widely identified extra cranial ossicles: epipteric bone, coronal ossicle, bregmatic bone, sagittal ossicle, apical bone, lambdoid ossicle, asteronic bone, ossicle in the occipito-mastoid suture, and parietal notch bone.

Scored traits that were previously mentioned, such as nasal form and nasal spine length, could fall within the hypostotic/hyperstotic class of non-metric traits, or potentially an additional fourth class of traits is widely being used in physical anthropology today. These other traits include differences in the manifestation of bony structures, such as the form that nasal bones assume or the shape of the bony nasal bridge. Rhine (1990) examines thirteen scored traits including: the length of the base chord, the base angle, bony orbit shape, nasal opening size, nasal bone formation, nasal spine length, nasal sill form, dental arcade shape, shape of chin, profile of chin in Frankfurt plane, the formation of the lower border of the mandible, and the thickness and angle of the ascending ramus of the mandible.

In addition to the non-metric skeletal traits involving bone, dental non-metric traits are also widely used in the determination of ancestry from the skeleton and in biodistance studies (Rhine 1990, Berry 1978). Dentition is particularly useful for biodistance studies and determining ethnic affinity because they preserve better than bone in the archaeological record. Ansorge also notes, “characters of the teeth are very promising, as they remain very stable during late ontogenesis” (Ansorge, 2001:3).

Since Hooton devised the first fairly comprehensive list of human non-metric skeletal variants in the 1930s, the types of non-metric traits being recorded and their determined genetic basis has changed throughout the decades. Studies have found that hypostotic/hyperstotic traits have a larger genetic component than foraminal and fusion traits (Cheverud and Buikstra 1981, 1982; Richtsmeier and McGrath 1986). Considering this, recent studies in ancestry determination from the skeleton and in biological distance have moved to more varied non-metric trait lists (Rhine 1990, Buikstra & Ubelaker 1994). While the genetic basis for non-metric traits continues to be an issue of contention in the sciences, heritability for certain traits has been successfully demonstrated through experimentation.

The Genetic Basis of Non-metric Skeletal Variants

Non-metric cranial and dental variation in animals became a prominent subject of research in the 1950s when researchers began to examine the genetic inheritance of non-metric traits (Griffin MC, 1989:Chapter 3). A consensus exists among scientists that non-metric traits are "epigenetic polymorphisms" and therefore are affected by both environmental and genetic influences (Griffin MC, 1989:Chapter 3). Debate continues on the degree to which non-metric skeletal traits are affected by environmental factors. Several early studies on mice argue for a strong genetic component to non-metric traits (Grüneberg 1952, Berry 196). While several considerations such as the influence of age and sex on the manifestation of traits are primarily left out of the early studies, these studies still successfully demonstrate patterns of inheritance in non-metric traits and identify evolutionary forces affecting their prevalence in certain populations. Three primary animal studies are relevant to research on human non-metric skeletal variation

Grüneberg (1952) carried out one of the earliest studies on the inheritance of non-metric skeletal variants entitled, "Genetical Studies on the Skeleton of the Mouse". For this study, Grüneberg crossbred two different strains of laboratory mice to observe the genetic inheritance of behavior and vertebral and pelvic skeletal variation. He concluded that non-metric variation in the skeleton is inherited multifactorally and is affected by the environment. After this experiment, Grüneberg introduced the principle of "quasi-continuity" which states that the inheritance of a discontinuous trait is due to the segregation of multiple genes in conjunction with the "threshold of manifestation" (Griffin, 1993: Chapter 3). This means that skeletal traits of a quasi-continous nature must be influenced by a certain number of genes in order to be expressed; it takes so many genetic factors to create the threshold at which a certain trait will manifest. The principle of quasi-continuity is particularly relevant to the method a researcher uses in scoring non-metric traits: recording techniques should record not only presence/absence but also numbers and degrees because the latter are under genetic control as well.

Berry's (1963) study, "Epigenetic Polymorphism in Wild Populations of *Mus musculus*", is perhaps the most notable and widely cited study to examine whether or not non-metric skeletal variants are under genetic control. His objective was to find more reliable and easier means for identifying small wild animals in a population without having to mark animals and track home ranges. For this, he set out to test whether populations of house mice sharing a common gene pool in nature possess a suite of non-metric skeletal traits. Approximately 50 house mice skeletons were taken from various parts of the world, including ten different localities in the United Kingdom. However, the bulk of the study and the basis of Berry's (1963) conclusions derives from the examination of fifteen different populations of house mice living on separate corn ricks[1] within a large farm in Hampshire, England. For each skeleton, Berry (1963) recorded 35 cranial and postcranial non-metric skeletal traits, including sites of bony fusion, the presence/absence of foramina, size and closure of foramina, bony fusion of vertebral elements, and presence of all vertebrae. Chi-square analyses were performed for each trait among rick populations, and the C.A.B. Smith Mean Measure of Divergence tests were performed among the whole data for each of the populations.

By focusing on the corn rick populations at the Hampshire farm, Berry was able to identify the sources of variation, because all fifteen rick populations originated from one main population of house mice. At the outset, Berry (1963) identified four ecological variables that could be contributing to the variation found in the mice skeletons: type of food mice were eating, geographic location, the number of animals invading each rick, and the selection for resistance to the poison Warfarin. Age and sex were not considered as contributing variables to variation in the mice skeletons. Based on his observation of the distribution of skeletal variation and statistical analyses, Berry (1963) concluded that there was a small diet effect on the group, but that the main source of variability among the ricks was geographic in nature (Berry, 1963). His data suggest that genetic drift occurred as the original population split and divided up among the ricks to form new populations. Furthermore, stabilizing selection was occurring in reaction to the introduction of the poison Warfarin into the rick populations. Berry's (1963) study was the first to demonstrate heritability patterns for non-metric skeletal markers.

[1] Ricks are stacks of hay or straw which have been covered and blocked off for protection from the weather.

A third study on mice carried out by Richtsmeier and McGrath (1986) examined the effects of differential fostering among mice to see how the postnatal environment affects the expression of non-metric traits. The results of this study found hypostotic/hyperstotic traits to be significantly more heritable than other classes of non-metric traits (fusional and foraminal) that are impacted by the development patterns of other tissues. For instance, the number and distribution of foramina is dependent upon the number and distribution of blood vessels and nerves. Therefore, foramina are less of an indicator of genetic relationships and more an indicator of development patterns. Such observations led Richtsmeier and McGrath (1986) to introduce the <u>Functional Matrix Hypothesis</u>, which states as the number of developmental resources increases, the heritability of a trait decreases. This means that if traits are arising during the development of the bone or other structures interacting with the bone during human growth, the likelihood that the trait has a genetic basis is lessened. Foramina are a good example of traits influenced by developmental processes because their number or placement is directly related to those structures developing through them (i.e. arteries, nerves). Further, Richtsmeier and McGrath (1986) are among the many researchers to elucidate the effect non-genetic factors have on the manifestation of non-metric skeletal traits.

In addition to the many genetic studies on non-metric traits in non-primates, several more recent studies have examined skeletal variation in non-human primates for the purpose of calculating population biodistance (Berry and Berry 1971, Cheverud and Buikstra 1981, 1982). Berry and Berry (1971) examined the distance among subspecies of several primate species, including *Gorilla gorilla, Hylobates lar, Pan troglodytes,* and

Pongo pymaeus. As Berry (1963) found with the geographic separation of the house mice in England, systematic skeletal variation existed among the subspecies of each primate species on the basis of geographic separation and thus reproductive isolation. With this study, Berry and Berry further asserted that a strong genetic basis for non-metric traits in the skeleton does exist.

Cheverud and Buikstra (1979, 1981, 1982) supported the use of non-metric traits as genetic markers in their study of Rhesus macaques. Using 297 individuals of both sexes and a range of ages, Cheverud and Buikstra calculated heritability values from correlation statistics for 24 non-metric variables. Their results demonstrated that hypostotic and hyperstotic traits have higher heritability variables than foraminal traits. This conclusion prompted the Richtsmeier and McGrath (1986) study on the heritability of traits in mice that led to the Functional Matrix Hypothesis. Again, the differential manifestations of those traits that are closely related to developmental processes involved in human growth are less likely to be genetically linked.

The previously discussed studies successfully create a genetic link with non-metric skeletal variants in animals. While environmental influences affect the expression of some non-metric traits, genes more heavily influence hypostotic/hyperstotic traits. Despite continued disagreement over the extent to which environmental factors play a role in the expression of non-metric traits, anthropologists have widely accepted that a genetic component to many non-metric traits exists (Larsen 1999). Some traits have been shown to have less heritability than others, however the heritability of non-metric skeletal variants matters less than the randomness of environmental influence over such traits (Larsen 1999:304). The large number of biological distance studies in the field that utilize non-metric trait analyses evinces their value in the evaluation of biological distance (Bennett 1965, Ossenberg 1969, Korey 1970, Buikstra 1980, Birkby 1973, Blakely 1973, Berry 1974, Corruccini 1974, Finnegan and Faust 1974, Saunders and Popovich 1978, Finnegan 1978, Kennedy 1981, Hennenberg et. al. 2001, Ullinger & Sheridan 2001, Praymak et. al. 2001, Cucina et. al. 2002, Nystrom 2002, Ullinger 2002, Wrobel 2002).

Non-metric Skeletal Variants and Biodistance Analysis in Physical Anthropology

The history of recording non-metric traits from the human skeleton traces back to Blumenbach in 1776 (Buikstra & Ubelaker, 1994: 85), but anthropologists did not begin looking at their possible genetic basis until the late 19th century (Shepherd 1893; Symmers 1895). The 1970s proved to be a period in physical anthropology when non-metric variation in the human skeleton was given much attention (Corruccini 1974, Finnegan 1974, Czarnetzki 1975, Finnegan 1978, Lane & Sublett 1978, Perizonius 1979, Anonymous 1979, Cheverud et. al. 1979, Cosseddu et. al. 1979, Finnegan & McGuire 1979). However, during the 1980s and 1990s, biological distance studies, which comprise the majority of studies on non-metric traits, tapered off.

Biological distance analysis, "a measurement of population divergence based on polygenic traits", was the dominant type of skeletal research in the 19th century (Buikstra et. al., 1990:1). Research in biological distance, according to Buikstra et. al. (1990), declined after the 1970s and has remained a less popular area of study in recent times. Investigations into the health and diet of past peoples have become the more prevalent form of research in physical anthropology since the 1970s, but researchers focusing on biological distance assert it is a necessity for biodistance analyses to be incorporated into paleopathology and paleoepidemiological research (Buikstra et. al., 1990).

Buikstra et. al. (1990) outline three motivations for continuing to examining biodistance in past populations as a means of addressing anthropological questions. First, biodistance can answer basic questions about evolutionary history. Population movement and migratory behaviors, the effects of genetic drift and gene flow, and factors that stabilize selection can be identified through the analysis of biodistance from the human skeleton. Secondly, biodistance analysis can be incorporated into archaeological research, assisting with defining regional groups and residence patterns. Further, biodistance analysis should serve as the background for all paleopathology and paleoepidemiological research. Because inquiries into past people's health, diet and morbidity/mortality rates are often used comparatively among populations, the biological distance among such populations is relevant to the research.

Despite the decline in biological distance studies since the 1970s, non-metric skeletal research continues in physical anthropology today (Powell & Neves 1999, Stefan 1999, Hennenberg et. al. 2001, Praymak et. al. 2001, Steadman DF 2001, Ullinger & Sheridan 2001, Corruccini & Shimada 2002, Cucina et. al. 2002, Nystrom 2002, Ullinger 2002, Wrobel 2002). Further, the focus on non-metric studies both in biological distance analysis and in the sub-area of ethnic/"racial" affinity determination has had a resurgence in the 1990s (Gill and Rhine 1990, Gill 1995, Gill 1998, Aubin 2002, Heffner 2002, Ousley 2002). These studies have focused on troubleshooting methods employing non-metric trait analyses: evaluating what traits are more reliable in determining biological distance or ethnic affinity and examining the limitations to the methodology.

Limitations to Non-metric Trait Studies

While many factors that can sway the results of non-metric trait data were largely ignored in earlier (1930s-1950s) studies, much research has occurred on the limitations of non-metric trait analysis in more recent years (Finnegan & Cooprider 1978, Molto 1979, De Stefano et. al. 1984, Gualdi-Russo et. al. 1999Ansorge 2001). These limitations include subjectivity of scoring (interobserver/intraobserver error), sex and age related differences in the human skeleton, asymmetry of non-metric traits, and inter-trait correlation.

The subjectivity of non-metric trait analysis will always remain a complication of this method. Interobserver error can oftentimes be linked to the experience of researchers recording the traits, and can be avoided by having a sole researcher record all traits (De Stefano et. al. 1984, Gualdi-Russo et. al. 1999). While this is not always possible, it is of note that non-metric interobserver error is less systematic than the interobserver error experienced with metric analyses, thus the impact interobserver error has on the interpretation of results in non-metric studies is less significant (Molto 1979:333). The reason metric analyses are more prone to systematic interobserver error is because researchers will tend to measure landmarks in a similar way throughout the measuring process. If a researcher consistently measures in an incorrect manner, all measurements will be off. Whereas with non-metric traits, interobserver error occurs more frequently with only one or so traits that are misunderstood by the researcher. While interobserver error is associated with all types of data collection, interobserver error in the recording of non-metric traits is largely related to the exactness and clarity of non-metric trait descriptions. It is therefore imperative that researchers meticulously describe their data and methods in non-metric trait studies.

Intraobserver error is more difficult to avoid. While researchers can, if possible, correct their own data through multiple analyses and discarding those traits with low precision scoring, the issue of intraobserver error is oftentimes less obvious. Furthermore even if the precision of scoring by one researcher is quite high, it is difficult to evaluate whether one researcher would label a manifestation of a trait the same as another. For instance, what one researcher would consider to be a "guttered nasal sill" another might record as "blurred nasal sill"; while the intraobserver precision of scoring may be high, the manner in which the trait is recorded may be different from one researcher to the next. This again can only be ameliorated through detailed descriptions of traits. Despite the possibility of intraobserver error, Molto suggests that intraobserver error is less systematic in nature and therefore less affective in the analysis of non-metric datasets (Molto 1979:342). Finnegan supports this claim and suggests that "interobserver error is much more critical in the published literature and more difficult to test than intraobserver error" (Finnegan 1978:393). This is a serious issue for non-metric studies, particularly for those in forensic anthropology. Interobserver error could be swaying the results of non-metric analyses of skeletal remains as many anthropologists attempt to employ methods devised and perhaps only clearly understood by a few people.

One of the primary arguments against Berry's (1963) study results, "Epigenetic Polymorphism in Wild Populations of *Mus musculus*", was his failure to analyze the effects of sex and age on the sample. Finnegan and Cooprider (1978) note that several researchers have reexamined Berry's claims that sex and age do not affect non-metric trait analyses. Such studies have found that certain traits are impacted by sexual dimorphism, however age has largely no impact on non-metric analyses. Further studies have shown that sex and age have a statistically insignificant impact on such analyses (Perizonius

1979; Cosseddu et. al. 1979). A small number of traits have typically been excluded from non-metric analyses of ancestry or biological distance in humans because of their tendency to be sex dependent (e.g. depression at nasion, gonial angle).

Asymmetry of non-metric traits and the method for scoring bilateral traits has been addressed in the literature (Cosseddu et. al. 1979, Ansorge 2001). Asymmetry is a result of environmental noise and is perhaps one of the developmental influences for which Richtsmeier and McGrath's (1986) model accounts. A recent look at asymmetry by Ansorge (2001) finds fluctuating asymmetry to be the impact of the environment over genetics (Ansorge 2001:7). However because fluctuating asymmetry is random, many researchers have dealt with this problem by being consistent in their methodology (Cosseddu et al. 1979, Ansorge 2001): recording all traits as bilateral sets or selecting one side to record consistently.

Another issue related to the heritability of traits and their use as independent markers of biodistance is that of inter-trait dependency. If the expression of one trait were contingent upon the expression of another, the use of both traits as genetic markers would be problematic. Fortunately, researchers have found correlations among traits to be so small that significance is irrelevant to the statistical analyses of non-metric trait data (Benfer 1969, Finnegan & Cooprider 1978) "Consensus thus holds that few traits can be shown to be statistically correlated; those that are can either be explained biologically, or they show a very *low* degree of association" (Finnegan & Cooprider 1978: 3). It can therefore be assumed that the genetic model holds true; independent genes result in disassociated traits (Finnegan & Cooprider 1978:3).

Considering these possible limitations, researchers have moved in the direction of identifying traits of heritable significance and providing better descriptive information on non-metric traits.

Current Direction of Non-metric Studies in Physical Anthropology

A search of the 2001 and 2002 American Association of Physical Anthropologists (AAPA) meeting presentations show continued research interest in non-metric skeletal variation. Non-metric studies deal with the following issues: ontogenetic development (Busby 2002, Hattman 2001, Lovejoy et. al. 2002), biodistance and settlement patterns (Cucina et. al. 2002, Hennenberg et. al. 2001, Praymak et. al. 2001, Ullinger & Sheridan 2001, Nystrom, 2002, Ullinger, 2002, Wrobel, 2002;), paleoanthropology (Hunley & Cabana 2001,Villmoare 2001, Durband et. al. 2002, Steininger 2002), and skeletal stress markers (Imber & Aiello 2001). Other current research in non-metric trait analysis focuses on the issue of race in forensic anthropology (Gill and Rhine 1990, Aubin 2002, Heffner 2002).

In addition to their continued use in establishing biodistance in archaeological populations, the subfield of forensic anthropology has heavily focused on the use of non-metric traits in the determination of "race" or ethnic affinity from the skeleton. Recent developments in this area include broadening the range of "racial" differences identifiable through non-metric analyses and better descriptions of traits. The nasal region, inner ear and palate are becoming the most reliable skeletal areas in determining ethnic affinity from the skull (Gill, 1998). Gill (1998) reiterates Rhine's statement that "an important step for making non-metric approaches more useful to forensic anthropologists, and other human osteologists, is the systematic testing of their utility in diagnosing racial affinity" (Gill 1998:310). Many researchers have followed through with this important step (Duray et. al. 1999, Aubin 2002, Heffner 2002).

In summary, non-metric traits are valuable tools for examining the lives and relationships of past peoples. While environment does contribute to the expression of non-metric traits, differential heritability exists among non-metric skeletal traits, and random environmental factors do not heavily influence non-metric analyses in determining biological distance.

Biodistance along with research on determining ethnic affinity of individuals from the human skeleton continue to be of value and a research focus in physical anthropology. Future research concerning non-metric human skeletal variants will further the field of physical anthropology's ability to examine a wide array of archaeological, evolutionary and biological questions

Chapter 3

MATERIALS

The Hyrtl Skull Collection

The 139 skulls from the Joseph Hyrtl Collection, housed in the Mütter Museum at the College of Physicians of Philadelphia, were acquired by the renowned European anatomist between 1848 and 1869 (Worden, 1995). During this period, Hyrtl served as professor of anatomy at the University of Vienna, Austria and conducted comparative anatomical studies at the Josephinum museum in Vienna. At the latter, Hyrtl collected a variety of specimens including anatomical preparations, as well as fish and amphibian skeletons, auditory ossicles from numerous species, and human skulls. Around the time of Hyrtl's retirement from the University of Vienna, his collections were dispersed, and the Mütter Museum purchased the skulls from Hyrtl in 1873 (Worden, 1995).

The 139 skulls were collected primarily from Central and Eastern Europe and all have identity cards, which have been translated into English from German, Latin or Italian. Place of birth, name, age, religion, occupation, cause of death and donor are recorded for most of the individuals in the collection. Some of this information was originally inscribed on the skulls themselves; however, much of the ink inscription has been lost to cleaning (Worden, 1995:108). There are fourteen female and 125 male individuals within the collection, and their ages range from eight to eighty years old with the most prevalently listed causes of death being trauma or disease. This collection is unique from many other collections in the United States today because a record has been kept for place of birth; thus specific ancestry information can be ascertained from the identity cards.

This uniqueness has made the Hyrtl Skull Collection of interest to those studying how ancestry can be determined from the human skull, including Joseph Hyrtl himself who maintained "individuals subsumed within [a] generic racial category did not necessarily have identical characteristics in the same combinations" (Kemper, 1970:56). The collection was shown to be anthropologically useful in the mid-1990s when two anthropologists from the Smithsonian examined and measured several Croatian and Serbian skulls in preparation for training Croatian anthropologists how to identify skeletal remains being excavated from mass graves in the Balkans (Worden,1995:110). My research continues to explore human skeletal variation within the Hyrtl Skull collection so as to further understand the presence of intrapopulational variation in Europe.

Of the 139 skulls within the Hyrtl Skull Collection, 122 will be included in this study. The total number of individuals has been reduced to include only adult males (to rule out sexual dimorphism as a contributing factor), and then further reduced to exclude a few individuals in the collection not of European or Middle Eastern origin. Because the information on each individual was collected during the mid-1800s, place of birth reflects a political geography that precedes both the Soviet Union and Yugoslavia and is distinctly different from modern-day political geography. Therefore many of the geographic locations specified on the identification cards have been subsumed by other modern-day nations. In an attempt to clarify origin, some individuals have been assigned, if possible, a modern origin; however, within the dataset, the originally stated place of birth is parenthesized next to the modern origin.

In addition to the data collected by the researcher, materials will also include data from a previous study conducted by Stanley Rhine, Ph.D. on a sample of skulls from the

Maxwell Museum Collection (1990). His study examined 45 non-metric traits on an "Anglo" sample (*n*=53) in addition to skulls of "Hispanic", "Indian" and "Black" ancestry. His total sample size is 87 individuals, 78 are contemporary and of known identity (Rhine, 1990:9). While the Hyrtl sample is not American in origin as is the Maxwell sample, individuals classified as "Anglo" would be classified as "European" in the classification system for ancestry used in forensic anthropology today. Therefore, the Hyrtl sample serves as a good comparison for the "Anglo" sample in Rhine's (1990) study.

Political Geography of 19th Century East Central Europe

The Hyrtl Collection is divided into geographic groups according to the Federation of East European Family History Societies Map Index (2001). This on-line map index (http://feefhs.org/maps/indexmap.html) provides an extensive collection of 19th century maps of Europe and accounts for all of the geographic places listed as places of birth in the Hyrtl Skull collection. Table 1 shows the division of the data.

The Geographic Grouping excludes two individuals with an unknown place of European birth, one individual listed as "Jewish", and one individual from Finland. Because the data does not divide into evenly distributed geographic groups, two of the groups are discarded in the analyses of the Geographic groupings: Switzerland (Region 4) and The Middle East (Region 6). Analyses of the crania in the Geographic groupings will include comparisons among all of the remaining groups.

Table 1: Regional Groups of Europe

Regional Group Name	Geographic Areas Encompassed by Region	Number of Individuals in Regional Group (n=118)
Austro-Hungary – Region 1	Austria, Bohemia, Czechoslovakia Galicia, Hungary Moravia, Slovakia, Stovenia, Trieste	38
The Balkans – Region 2	Albania, Bosnia-Herzegovina, Bulgaria, Carpathian Mountains, Crete, Croatia, Greece, Moldavia, Romania, Serbia	35
The Baltics – Region 3	Belarus, Caucasus, Crimea, Poland, Russia, Ukraine	17
Switzerland – Region 4	Switzerland	4
Italian Peninsula – Region 5	Italy, Malta	19
The Middle East – Region	Turkey, Armenia, Kurdistan,	5

Regional Groups of Europe, Federation of East European Family History Societies (2001)

Ethnolinguistic Relationships of 19th Century East Central Europe

The data were also divided into seven ethnolinguistic groups based on The Historical Atlas of East Central Europe (Sugar & Treadgold,1993). This atlas divides the region of East Central Europe into most closely related groups of people as based on the history of their languages and ethnic backgrounds. Table 2 shows the division of the individuals according to ethnolinguistic background.

All of the crania in the ethnolinguistic groupings with the exception of the "other" group are compared against one another in the Chi-Square tests and Mean Measure of Divergence Tests.

Table 2: Ethnolinguistic Groups of Europe

Ethnolinguistic Group Name	Geographic Areas Encompassed by Group	Number of Individuals in Ethnolinguistic Group (n=122)
Germanic Group	Austria, Switzerland	18
East Slavic Group	Bohemia, Czechoslovakia Galicia, Hungary Moravia, Slovakia, Stovenia, Trieste	18
West Slavic Group	Belarus, Caucasus, Crimea, Poland, Russia, Ukraine	14
South Slavic Group	Albania, Bosnia-Herzegovina, Bulgaria, Carpathian Mountains, Crete, Croatia, Moldavia, Serbia	17
Finno-Ugric Group	Finland, Hungary	12
Romance Group	Italy, Malta, Romania	27
Other	Turkey, Armenia, Kurdistan, Lebanon, Greece, Jewish, Unknowns	16

Ethnolinguistic Grouping of Europe: The Historical Atlas of East Central Europe (Sugar & Treadgold,1993)

Chapter 4

METHODS

Data Collection Methods

A total of nineteen non-metric traits will be used in this study. Eighteen of the non-metric traits were evaluated from the Hyrtl sample (*n*=122) at the Mütter Museum of the College of Physicians of Philadelphia during the week of August 12, 2001-August 18, 2001. These eighteen traits appear in Rhine's (1990) list of 45 non-metric traits (Rhine, 1990:Table 2). The original number of traits used in Rhine's (1990) study was reduced to eighteen to reflect those traits deemed to be of significance to the "American Caucasoid" individuals in Rhine's (1990) study. These eighteen traits were also chosen for their predetermined value in the determination of ancestry from the human skull (Gill, 1998); ease to collect and correctly evaluate; and tendency to be less subjective in nature. An attempt to balance these three factors was made, and a few traits originally collected have been discarded because the trait was perhaps better evaluated metrically (i.e. base chord, see Rhine (1990:19)) or not included in the Rhine (1990) study (i.e. parietal foramen, supraorbital foramen, and occipital shelf). Some of the latter traits, particularly the presence or number of foramina, have been de-emphasized in recent studies of ancestry determination from the human skull (Gill, 1986; Gill, 1998)

The following is a description of each non-metric trait used to evaluate the Hyrtl sample and the manner in which the trait was evaluated for this research. These descriptions are derived from Rhine's (1990) list of traits (Rhine, 1990:Appendix, 19-20). An attempt was made to replicate Rhine's (1990) method for evaluating the following non-metric traits:

Metopism: Partial or complete metopism; an incomplete/complete persistence of the metopic suture in the area immediately superior to nasion. Any presence of metopism (complete/incomplete) is listed as present.

Wormian Bones: Extra ossicles formed by the complexities of the sutural course, particularly in the lambdoidal and sagittal sutures. Any extra ossicles found along the lambdoid suture is listed as present.

Canine Fossa: Depression in the maxillae at the root of the canine. Any degree of depression is listed as present.

Inion Hook: An inferior projection of the external occipital protuberance. Any degree of projection is listed as present.

Nasal Spine: Amount of outward projection of the nasal spine. Scored as being long, medium or short.

Nasal Sill: Area where the vertical maxillae create a sharp ridge separating the nasal cavity from the maxillae. If the ridge is high, it is scored as "deep"; if shallow, it is scored as "shallow"; if a sharp ridge is lacking, it is scored as "blurred"; and if a smooth curve leading into the nasal aperture without interruption is present, it is scored as "guttered". Scored according to criteria: deep, shallow, blurred, or guttered.

Base Angle: This is the angle formed by the basion-opisthion plane compared to a plane projected posteriorly from the palate. Scored as high or low by laying a 3 mm wide, 12-inch instrument through the described planes.

Depression at Nasion: Depression just inferior to nasion at the deepest point of curvature of the nasal bones. Scored as depressed or flat.

Nasal Form: General form of the nasal bones as being high and steeply angled (Steepled), wider and slightly concave (Tented), or low and smoothly rounded (Quonset Hut). Scored according to criteria as one of the following tented, steepled, or quonset hut.

Maxillary Prognathism: Slight alveolar projection of the maxilla. Scored as present or absent.

Carabelli's Trait: The bilateral presence of either a full or partial (trait) supernumerary cusp on the first molars. Any presence of Carabelli's trait (cusp/trait) is listed as present.

Molar Crenulations: A complex wrinkling of the mandibular molar crowns. Deviation of the mandibular molars from a classic Y-5 pattern listed as present.

Incisor Shoveling: Slight lingual indentation of incisors. Scored as present or absent.

Undulating Lower Border of Mandible: A deviation of the lower border of the mandible upwards from a plane when mandible is placed on a flat surface. Scored as undulating, slightly undulating or flat.

Ascending Ramus Angle: Angle of ascending ramus; either vertical with the posterior border near 90° or slanted with an angle greater than 90°. Scored as either straight or slanted.

Oval Window: Small oval opening located inside the ear canal and either visible or not visible through the external auditory meatus. Scored as visible bilaterally or not visible bilaterally.

Zygomaticomaxillary Suture: Suture joining the medial aspect of the zygomatic bone with the lateral aspect of the maxilla is either S-shaped or angled. Scored as curved or angled.

Venous Markings: Grooves present on the frontal bone seen slightly superiorly to the temporal lines, superior to the orbits. Any number of venous markings on the frontal bone listed as present.

For additional information on the methodology, *Appendix A* is an example of the original data collection sheet.

The researcher and an assistant transported approximately twenty skulls at a time from the display case to an examination room where each skull was scored/evaluated for the given non-metric traits. This evaluation was blind as the skulls were not arranged in the case by ancestry nor were the skulls themselves marked with ancestry information.

The nineteenth trait, nasal opening, was derived from the research of Jennifer Eberly, a graduate student of Temple University in Philadelphia, PA. She collected metric data from the Hyrtl Skull Collection on nasal height (nasion-nasospinale) and nasal breadth (alare-alare) and from these measurements calculated a nasal index. The formula for the nasal index is the dividend of nasal breadth and nasal height multiplied by 100 (Thomas, 1997:1269). These data were collected using sliding calipers that measure distance in millimeters. These metric data have been converted into categorical data with three classifications for the range of the nasal index and are now included in the non-metric dataset. The three classifications represent the size of the nasal aperture and are listed with their respective index parameters in Table 3.

Table 3: Classification System for Nasal Index[2]

Classifications for the Nasal Index Range	Nasal Index Range	Corresponding Classifications for Nasal Opening from Rhine (1990)
Leptorrhiny	<47.99 mm	Narrow
Mesorrhiny	48.00 mm – 52.99 mm	Medium
Platyrrhiny	>53.00 mm	Wide

The conversion of the quantitative data has been done to maintain consistency in the analysis of the data and for comparative purposes since these data can now be compared to Rhine's (1990) frequencies for nasal opening size. Permission to use Eberly's data has been granted for this study by the researcher. Statistical analyses have been applied to the data as a whole (one European sample) and to the data of regional/ethnolinguistic groups present within the Hyrtl sample.

Statistical Treatment of Entire Dataset

One type of analysis was performed on the entire Hyrtl sample dataset: Chi-Square statistics among the Hyrtl sample counts and the expected percentages listed in Rhine (1990) for each of Rhine's (1990) four subgroups. To test Null 1-The European Definition Hypothesis and Null 2-The European Distinction Hypothesis, a Chi-Square statistic was computed for each of the nineteen traits four times using Rhine's (1990) frequencies for his four ancestry groups – "Anglo", "Hispanic", "Indian", and "Black" - as expected values (Rhine, 1990:Table 2). When $p<0.05$, the trait frequencies for each will be considered statistically different between the Hyrtl sample and Rhine's (1990) "Anglo" sample, and Null 1-The European Definition Hypothesis rejected for that trait. If Chi-Square analyses computed among the Hyrtl sample and Rhine's (1990) three non-

[2] Nasal Index definition from Moore-Jansen et. al. (1994)

European ancestral groups – "Hispanic", "Indian", and "Black" – are not significantly different ($p>0.05$) for any given trait, then the Null 2-The European Distinction Hypothesis will be accepted for that trait.

Table 7, *Appendix B* shows Rhine's (1990) expected outcome for each trait among Rhine's subsamples (Anglo, Hispanic, Indian and Black) and the relationship among these subsamples as they pertain to each given trait. Because each of the traits being examined may not all be expected as "present" in a European sample, Table 7, *Appendix B* is used in the determination of whether a given trait rejects Null 1-The European Definition Hypothesis.

If Null 1-The European Definition Hypothesis is rejected for a given trait and Null 2-The European Distinction Hypothesis accepted, then the particular non-metric trait's significance in the determination of European ancestry should be devalued since the variation seen among ancestral groups for that non-metric trait may be due to random events and not geographically specific morphological variation.

Expected Results for Statistical Treatment of Entire Dataset

For those variables which are listed as expected for individuals classified as "American White" by Rhine (1990), it is anticipated that presence for these variables will be high in the Hyrtl sample. For those variables listed as being more prevalent among other ancestral groups (i.e. Hispanic, Indian or Black by Rhine (1990)), a reverse trend is expected.

Chi-Square analyses among the Hyrtl sample and those expected frequencies listed by Rhine (1990) for his 4 subgroups - Anglo, Hispanic, Indian and Black – should reveal a pattern. If Rhine's (1990) percentages for non-metric traits (Rhine, 1990:Table 2) truly reflect expected trait frequencies in the populations, then Chi-Square analyses of traits found to be "expected" in American Caucasoids should indicate no significant statistical difference ($P>0.05$) between Rhine's Anglo subgroup and the Hyrtl sample. Further there should be statistically significant differences found among those traits deemed exclusive to any particular ancestral group(s) other than Anglo (Hispanic, Indian or Black). If any trait is expected for one particular ancestral group or pair of ancestral groups, then Chi-Square analyses should show statistically significant differences ($P>0.05$) among this/these groups and those ancestral groups for which the trait is not expected. For example, the non-metric trait "metopism" is expected, according to Rhine (1990), to appear in both "Anglos" and "Hispanics", however not in "Indians" or "Blacks" (Rhine, 1990:16). Therefore, Chi-Square tests should show statistically insignificant P-values among the Hyrtl Sample and Rhine's "Anglo" and "Hispanic" samples. Statistically significant P-values would be expected among the Hyrtl sample and Rhine's "Indian" and "Black" samples.

Statistical Treatment of Geographic and Ethnolinguistic Subgroups

Three types of analyses were performed on the geographic/ethnolinguistic subgroups: descriptive statistics, bivariate statistics, and a multivariate analysis for each grouping. For descriptive analysis, clustered bar charts of each non-metric variable were created for the six main ethnolinguistic subgroups and the four main geographic subgroups.

Two-way tables, Chi-Square Analyses, and where cells violated the Chi-Square assumption of a minimum count of 5, Fisher's Exact (2-Sided) tests were performed as bivariate analyses. All of these analyses were performed on the Geographic Subgroups and then the Ethnolinguistic Subgroups separately. Instead of performing an overall comparison of all subgroups in a grouping for a given trait, more precise analyses were performed. For each non-metric trait, a Chi-Square or Fisher's Exact Test, where appropriate, were computed to examine whether a statistically significant difference exists between any one subgroup and each of the other subgroups. For example, in the Geographic Grouping, a Chi-Square Table exists for "Austro-Hungary". Chi-Square results in this table show the Chi-Square Test Statistic, P-Value and degrees of freedom for each trait as compared among Austro-Hungary and the three other subgroups individually. This allows the researcher to examine between which two subgroups statistically significant results appear.

For both the Geographic Grouping and the Ethnolinguistic Grouping, a Freeman-Tukey transformation was performed on all of the variable counts to obtain means for the datasets. Green and Suchey (1979) suggest that non-metric cranial data be transformed according to the Freeman-Tukey transformation (Green and Suchey, 1979:67), which is as follows:

$$\text{New Value} = \tfrac{1}{2}\sin^{-1}(1-2k/(n+1)) + \tfrac{1}{2}\sin^{-1}(1-2(k+1)/(n+1))$$

This transformation stabilizes the variance to approximately $1/(n+\tfrac{1}{2})$ and best reduces the likelihood of falsely rejecting the null hypothesis (Green and Suchey, 1979:65). From these means, the C.A.B. Smith's Mean Measure of Divergence (MMD) was performed to examine the distance among each of the subgroups. Geographic subgroups were run against all of the other geographic subgroups, and Ethnolinguistic subgroups were run against all other Ethnolinguistic subgroups. From the distance measures, a Hierarchical Cluster Analysis, using Ward's Method, was performed for both the Geographic

Grouping and the Ethnolinguistic Grouping.

Expected Results for Statistical Treatment of Geographic and Ethnolinguistic Subgroups

For bivariate analyses, if all geographic subgroups should be classified under one ancestral category, "European", then there should be no statistically different results among any of the subgroups either within the geographic or the ethnolinguistic groupings. Particular note will be taken of how great the fluctuation in P-values is for the Chi-Square statistics among the different geographic/ethnolinguistic subgroups. If particular traits do have statistical differences between certain groups, it could be concluded that these traits are of greater significance in the determination of ancestry than others.

For multivariate analyses, the distance between each of the subgroups in both groupings are not expected to represent the true distance between these populations. Because the MMD measure is sensitive to sample size and the sample sizes of most subgroups being compared are less than 20, the results may appear less significant than perhaps they truly are. Despite this, it is expected that distance measure will demonstrate which of these populations are most closely related.

Chapter 5

RESULTS OF STATISTICAL TESTS

Results of Chi-Square Analyses for Entire Dataset

Chi-Square was performed for each variable in the Mutter dataset four separate times, comparing each variable to Rhine's Anglo subgroup, Hispanic subgroup, Indian subgroup, and Black subgroup. Rhine's (1990) dataset is problematic for Chi-Square because some of his results do not meet the minimum cell frequency assumption necessary to run Chi-Square. This is in part due to his small subgroup sample sizes (see Table 4), but also due to very low frequency of certain traits. For example with the Rhine's (1990) Anglo subgroup, 100% of the individuals express a low base angle; therefore the expected frequency for high base angle is less than five individuals, thus violating the assumption (Rhine, 1990).

Table 4: Rhine's (1990) Maxwell Collection Sample

Rhine's (1990) Subgroup	Number of Individuals
Anglo	53
Hispanic	15
Indian	12
Black	7

It is questionable if any statistic can robustly examine Rhine's (1990) data for the smaller subgroups; this is one of the problems with utilizing Rhine's (1990) study to justify determination of ancestry from the human skull. I will discuss the results of all statistical tests, yet have found that the Anglo subgroup allows for the most reliable results of the four subgroups due to the larger sample size. Table 8, *Appendix B* in this section shows the results of the comparative analysis among the frequency of the given variables in the Hyrtl sample and the corresponding frequencies given in Rhine (1990). Traits that produced error results were discarded from the final analysis. Disregarding these variables, fourteen variables were tested and the table shows that six variables show a statistical difference between Rhine's "Anglo" data and the Mütter data: metopism, nasion depression, slight prognathism, Carabelli's Cusp, zygomaticomaxillary suture, and venous markings. Another four variables shown do not reflect the pattern of expected traits listed in Rhine's Figures 1,2,3 (Rhine,1990:10-12) and are statistically similar to Rhine's non-European subgroups: nasion depression, Carabelli's Cusp, zygomaticomaxillary suture, and venous markings. When examining the statistical results, it is important to note that Hispanic is a new ancestry category and has been researched very little. Ultimately, Rhine includes Hispanics in his "Caucasoid" sample count and does not distinguish between "White" and "Hispanic". It is also of note that some of the statistical results demonstrated significant differences between the Rhine (1990) study and the Hyrtl study, however the null hypothesis could not be rejected for some of these traits. The reasoning behind this conclusion is that the Hyrtl sample better supported Rhine's (1990) conclusions than his own data. For many traits listed as expected by Rhine (1990), his data indicated reverse trends and so therefore the Hyrtl data conflicts with his results. This scenario occurs for both the traits nasal opening and nasal spine. For example with the nasal opening trait, Rhine (1990) indicates that a narrow nasal opening is expected for Caucasoids however less than half of his sample expresses a narrow nasal opening. Further an equal number have what Rhine classifies as a "medium" nasal aperture (Rhine, 1990:14-16). Approximately 67% of the Hyrtl skulls express a narrow nasal opening, resulting in a statistically significant P-value for the trait.

Res

of t

Co

(be

ma

R

o

C

l

r

Results for Chi-Square Analyses for The Geographic Subgroups

The set of Tables found in *Appendix C* show the Chi-Square results among each of the subpopulations for 18 traits. Seven of these traits reject Null 3-The European Trait Consistency Hypothesis at a P-value equal to or less than 0.05 on at least one occasion (between at least one set of populations): nasion depression, nasal sill, undulating mandible, ascending ramus, oval window and Wormian bones.

Results for Chi-Square Analyses for The Ethnolinguistic Subgroups

The set of Tables found in *Appendix D* show the Chi-Square results among each of the subpopulations for 18 traits. Seven of these traits reject Null 3-The European Trait Consistency at a P-value equal to or less than 0.05 on at least one occasion (between at least one set of populations): metopism, nasion depression, Carabelli's Cusp, venous markings, nasal sill, nasal opening, and venous markings.

Results for Mean Measure of Divergence Tests

As anticipated, Null Hypothesis 4 cannot be rejected. The results of the Mean Measure of Divergence tests for the Geographic and Ethnolinguistic Subgroups appear in Table 5 and Table 6 respectively. Rejection of the hypothesis was determined by the statistical software program.

Table 5: Mean Measure of Divergence Values Geographic Groups

Population Group 1	Population Group 2	MMD	Standard Deviation for MMD	Test Statistic	df
Austro-Hungary	The Balkans	0.011506	0.019266	22.37	18
Austro-Hungary	The Baltics	-0.004325	0.031109	18.29	18
Austro-Hungary	Italian Peninsula	0.012798	0.027088	21.46	18
The Balkans	Italian Peninsula	-0.021993	0.027744	13.67	18
The Balkans	The Baltics	-0.009377	0.031784	17.11	18
Italian Peninsula	The Baltics	0.031328	0.039542	24.18	18

For the Geographic Grouping, the Austro-Hungary and The Baltics Subgroups are most closely related and are distinct from the Italian Peninsula Subgroup and The Balkans Subgroup which are significantly less related than the former pair. *Appendix E* shows the cluster analysis which demonstrates the relatedness of the above four Geographic groups.

Table 6: Mean Measure of Divergence Values Ethnolinguistic Groups

Population Group 1	Population Group 2	MMD	Standard Deviation for MMD	Test Statistic	df
Romance Group	Finno-Ugric Group	0.32459	0.049827	18.48	15
Romance Group	East Slavic Group	-0.030197	0.036243	10.87	15
Romance Group	West Slavic Group	-0.034418	0.041051	10.75	15
Romance Group	German Group	-0.015694	0.035835	13.21	15
Romance Group	South Slavic	-0.004566	0.036071	14.75	15
Finno-Ugric Group	German Group	0.004512	0.057028	15.99	15
Finno-Ugric Group	East Slavic Group	-0.045711	0.057295	9.71	15
Finno-Ugric Group	West Slavic Group	0.021658	0.061922	16.63	15
Finno-Ugric Group	South Slavic Group	0.037822	0.056922	18.74	15
South Slavic Group	German Group	-0.000569	0.043434	15.49	15
South Slavic Group	East Slavic Group	0.023549	0.043898	18.33	15
South Slavic Group	West Slavic Group	-0.032750	0.048769	11.69	15
West Slavic Group	East Slavic Group	0.000638	0.048864	15.08	15
West Slavic Group	German Group	0.006760	0.048414	16.59	15
East Slavic Group	German Group	-0.000092	0.043621	15.51	15

For the Ethnolinguistic Grouping, the German Subgroup and the West Slavic Group are most closely related, and share a close relationship with the South Slavic and Italian Subgroups. These four subgroups are less related to the East Slavic and Finno-Ugric Subgroups which share a relationship with one another. *Appendix E* shows the cluster analysis which demonstrates the relatedness of the above six Ethnolinguistic groups.

Summary of Hypotheses Testing

Hypotheses

<u>Null Hypothesis 1 - European Definition Hypothesis</u>: The non-metric data collected will demonstrate there to be no statistically significant difference in the distribution of discrete/quasi-continuous trait frequencies between the Hyrtl Skull Sample and Rhine's (1990) "Anglo" sample from the Maxwell Museum Collection.

<u>Null Hypothesis 2 - European Distinction Hypothesis</u>: The non-metric data collected will demonstrate there to be no statistically significant differences in the distribution of discrete trait frequencies between the Hyrtl Skull Sample and any of Rhine's (1990) three non-European groups.

<u>Null Hypothesis 3 - European Trait Consistency Hypothesis</u>: None of the traits in the dataset will be statistically different between the created subgroups.

<u>Null Hypothesis 4 - European Regions Hypothesis</u>: The means of the data will not be statistically different between regional/ethnolinguistic groups within the Hyrtl sample, supporting the notion that there is no statistically significant variation in the distribution of non-metric or metric traits among people with European ancestry.

- Null Hypothesis 1 can be rejected for the following non-metric traits (14 traits ran valid tests):
  - Metopism
  - Nasion Depression
  - Slight Prognathism
  - Carabelli's Cusp
  - Zygomaticomaxillary Suture
  - Venous Markings

- Null Hypothesis 2 can be accepted for the following non-metric traits (14 traits ran valid tests):
  - Nasion Depression
  - Carabelli's Cusp
  - Zygomaticomaxillary Suture
  - Venous Markings

- Null Hypothesis 3 can be rejected for the following non-metric traits among the Ethnolinguistic Grouping (18 traits ran valid tests):
    - Metopism
    - Nasion Depressed
    - Carabelli's Cusp
    - Venous Markings
    - Nasal Sill
    - Nasal Opening

- Null Hypothesis 3 can be rejected for the following non-metric traits among the Geographic Grouping (18 traits ran valid tests):
    - Nasal Sill
    - Nasion Depressed
    - Undulating Mandible
    - Ascending Ramus Profile
    - Oval Window
    - Wormian Bones

- Null Hypothesis 4 is accepted. No statistically significant difference exists among the means of the Hyrtl sample subgroups.

Chapter 6

DISCUSSION

The major trends in this dataset indicate that differences do exist among subpopulations in Europe. Despite the small size of the study collection and its geographic limitations, this study rejects several traits as being universal to all European groups. It is interesting to note that many of these traits are specific to the nasal region, a newer morphological area of focus in studies of human variation and the determination of ancestry, and that such traits may be of more significance in the differentiating among groups of people.

A review of my statistical tests and results indicates that Null 1-The European Definition Hypothesis and Null 3-The European Trait Consistency Hypothesis can be rejected for certain traits. While Null 2-The European Distinction Hypothesis can be accepted for a number of traits, and Null 4 - The European Regions Hypothesis cannot be rejected due largely to small sample size.

Null 1-The European Definition Hypothesis is rejected for six of the fourteen valid traits, meaning that these six traits were statistically different among their frequency of occurrence in the Hyrtl Sample and the Rhine (1990) "Anglo" sample. Four of these six traits also violate Rhine's conclusions by being more similar to "non-European" ancestral groups. Null 2-The European Distinction Hypothesis is accepted for these four traits, indicating that not only were the frequency of occurrence statistically different between the Hyrtl Sample and Rhine's (1990) "Anglo" sample, but that there were statistically similar to the three other "non-European" ancestral groups. Therefore, these four traits - Nasion Depression, Carabelli's Cusp, Zygomaticomaxillary Suture and

Venous Markings - do not correspond with Rhine's (1990) conclusions that they distinguish "Europeans" from other ancestral groups not sharing the specific trait expressions. These traits were not reliable in the evaluation of ancestry from the Hyrtl sample, and their use in other studies or forensic anthropology cases as indicators of ancestry should be questioned.

Null 3-The European Trait Consistency Hypothesis is tested twice, once with the Ethnolinguistic Subgroups and again with the Geographic Subgroups. For both tests, eighteen non-metric traits ran valid tests. The Ethnolinguistic Subgroup Chi-Square analyses show that among at least two of the six subgroups a significant P-value was obtained for six of the non-metric traits - metopism, nasion depressed, Carabelli's Cusp, venous markings, nasal sill and nasal opening. The statistical differences among the subgroups for these six traits indicate that these traits may be better traits for distinguishing European groups from each other on the basis of ethnolinguistic lines. The Geographic Subgroup Chi-Square analyses show that among at least two of the four subgroups a significant P-value was obtained for six of the non-metric traits - nasal sill, nasion depressed, undulating mandible, ascending ramus profile, oval window and Wormian bones. The statistical differences among the subgroups for these six traits indicate that these traits may be better traits for distinguishing European groups from each other on the basis of geographic lines. While different traits were rejected for Null Hypothesis 3 for each of the groupings, Ethnolinguistic and Geographic, both groupings show that for the Hyrtl data, Europe could be divided along geographic and ethnolinguistic lines with equal validity. There is no evidence in this study to suggest that narrowing the ancestral group "European" based on ethnolinguistic divisions would be any more valid that narrowing it based on geographic distance. Considering this, there is evidence that differences among the created subgroups do exist for six of the eighteen traits tested. On five such occasions, the non-metric traits distinguishing the subgroups involves the nasal region, supporting Gill's (1998) discussion on the value of the nasal region in determining ancestry from the human skull (Gill, 1998:304-305). Therefore, based on the results of this study, there is evidence to suggest that the area of Europe could be better defined for non-metric ancestry determination purposes.

Null 4-The European Regions Hypothesis set out to use the C.A.B. Smith's Mean Measure of Divergence (MMD) test to demonstrate a statistical difference among the total mean trait frequencies among subgroups so at to further support the narrowing of the ancestral category "European". The MMD test is sensitive to sample size differences and unfortunately the division of the Hyrtl sample into four geographic subgroups and six ethnolinguistic subgroups left small, unbalanced samples to test. Null Hypothesis 4 could not be rejected, and the MMD results do not support the division of the ancestral category "European" into smaller ancestral groups. More data is needed for the narrowing of the ancestral category "European".

Previous studies on non-metric craniofacial and dental morphology have failed to determine where the geographic lines of distinction lie for craniofacial and dental morphology. This is to say that no study has demonstrated craniofacial and dental traits to be solely specific to the area encompassing all of Europe and the Middle East. These geographic lines have been drawn to a certain degree arbitrarily, and it cannot be said that once these geographic boundaries have been crossed, morphology is distinctly different. Despite this, it has been proposed that individuals who appear to be "White" or generally of European descent tend to share suites of non-metric traits. To a certain extent, the study shows this to be true for eight of the traits listed as expected by Rhine, however, it is clear from the Chi-Square analyses that further analyses must be undertaken.

There has been no known test of Rhine's (1990) study that has examined the validity of his list for expected non-metric traits associated with "American Caucasoids" or individuals with European ancestry. Because Rhine's (1990) number of individuals for "Anglos" is only 53, less than half the size of the Hyrtl sample, it is possible that further research will continue to identify the problems with Rhine's (1990) original expected trait list (Rhine,1990:9-11).

It is expected that future research will provide better indicators for the determination of ancestry from the skeleton. A few anthropologists have alluded to the fact that more geographically specific criteria for the determination of ancestry would be useful and is already being practiced. Kennedy (1995) notes that he is fairly confident assigning ancestry based on the non-metric variation in individuals from the Indian subcontinent and Sri Lanka according to geographic sectors due to his extensive paleodemographic work in the area for many years. Further, he states that he would feel less confident doing the same with skeletons from another area of the world (Kennedy, 1995:799). Howells' (1995) metric analyses of crania have divided Europe into four ancestral categories: Norse, Zalavár, Berg, and Egypt. He has further divided other major geographic areas of the world into twenty-four ancestral categories based on cranial metric variation (Howells, 1995:4-5). This demonstrates that geographically specific regional variation does exist for Homo sapiens, and that anthropologists are justified in using more discriminating ancestry categories in the determination of ancestry.

Chapter 7

CONCLUSIONS

Summary

This study contributes to the general understanding of human variation in physical anthropology. While biological race has long been rejected as a valid concept by most physical anthropologists, the idea that variation in human morphology can tell anthropologists about past peoples is still vital. Forensic anthropologists take our knowledge of human variation and apply it to help depict the appearance of an individual during life from the morphology of their skeletal remains.

Techniques used for determining ancestry from the human skull non-metrically have not been sufficiently documented. Research in the area of non-metric ancestry determination will strengthen forensic anthropologists' understanding of craniofacial and dental morphological variation. These statistical analyses address the questions proposed at the outset of this project. While there is little control over the collection sizes available to researchers, the sample size for this project did impact the results. I hope in future studies that sample size will have less of an impact on the statistical results.

Despite research problems related to sample size, this study in addition to research I have recently conducted at the Smithsonian Institution's National Museum of Natural History on 600 skulls of known "Asian" ancestry brings into question the validity of the current assignment of expected non-metric traits to the three main ancestry categories - European, Asian and African. Statistical tests on the Hyrtl sample indicate that a good portion of the trait list found by Rhine to be expected in his fifty-three individuals of "Caucasoid" descent were not present in the same frequency in the Hyrtl samples' 122 individuals. As anticipated, the trait list proposed by Rhine (1990) is most probably population or collection specific. The follow-up question to this problem would be whether the methodology on a whole is truly dependent upon population variation and is not as wide-sweeping as perhaps depicted in non-metric trait studies (Gill & Rhine, 1990). Based on my research, the former seems true; non-metric cranial traits vary from population to population and cannot describe an entire group of populations deriving from a general region such as Europe or Asia. This is important particularly for forensic anthropologists employing Rhine's (1990) methodology for the determination of ancestry. One of the following is needed in the field of forensic anthropology in order for non-metric trait methodology to be a viable medico-legal method for the determination of ancestry: 1) additional research on non-metric trait variation which can substantiate the inclusion of several populations into one ancestral category, or 2) an abandonment of the use of non-metric traits as a sole means for determining ancestry from the human skull.

Future Research

Further research on the use of non-metric skeletal variants in the determination of ancestry from human skeletal remains is currently being carried out by the author at the Smithsonian Institution, National Museum of Natural History (NMNH). The current project will examine the accuracy of Rhine's expected non-metric skeletal trait list for "Southwestern Mongoloids" or individuals with Asian ancestry on a sample of human skeletal remains of Asian or Native American descent housed at the NMNH. From these collections, my research sample includes 600 adult individuals of both sexes: seventy-six Chinese, sixty-two Alaskan Inuit, sixteen Japanese, five modern Asian, 204 Mongolian, seventy-one Native American's from the Southwest region (Arizona & New Mexico), seventy-three Native American's from the Midwest region (Illinois), fifty-three Peruvians, and forty Siberians.

Rhine's (1990) skeletal sample for individuals of Asian ancestry is restricted to the U.S. Southwest region. Rhine acknowledges, "this sample represents only a very small fragment of the continuum of variability which makes up the Mongoloid group" (Rhine, 1990:13). Despite this, Rhine's (1990) list of skeletal traits provides a good foundation for the examination of non-metric traits in skeletal populations. Furthermore, the literature in the United States on the distribution of non-metric skeletal traits for Asian populations is not as extensive as for African or European populations, and Asian individuals in general are often compared to those non-metric traits expected for Rhine's (1990) "Southwestern Mongoloid" category.

The goal of this study is to continue to examine the value of non-metric traits in distinguishing individuals from one another along more narrowly defined ancestral borders. If the results from this research find that, as with this project, several traits are more valuable in distinguishing subgroups of individuals currently classified as being of "Asian" ancestry, anthropologists should consider revising the current classification system for ancestry as it is used in forensic anthropology today.

APPENDICES

APPENDIX A

Original Data Collection Sheet

The Mütter Museum: Hyrtl Skull Collection Data Sheet

Institution: The Mütter Museum/College of Physicians of Philadelphia
Researcher: Valerie N. Yavornitzky
Association: Michigan State University
Skull Number:____________________________
Data Sheet Number: _______________________

Non-Metric Trait	Presence/Absence	Completeness/Degree	Comment
1. Metopism			
2. Wormian Bones			
3. Canine Fossa			
4. Supraorbital Struc.			
5. Inion Hook			
6. Nasal Spine			
7. Nasal Sill			
8. Parietal Foramen			
9. Base Chord			
10. Base Angle			
11. Occipital Shelf			
12. Nasion			
13. Nasal Shape			
14. Prognathism			
15. Carabelli's Cusp			
16. Molar Crenulation			
17. Incisor Shoveling			
18. L. Border Mandibl			
19. Ascending Ramus			
20. Oval Window			
21. Zygomatico Sut.			
22. Venous Markings			

APPENDIX B

Chi-Square Results for Entire Dataset

Table 7: Expected Traits per Ethnic Group from Rhine (1990:Table 3)

Variable	Anglo Subgroup	Hispanic Subgroup	Indian Subgroup	Black Subgroup	Trait Differs Between Which Groups?
Metopism	Expected	Expected	Not Expected	Not Expected	A,H vs. I,B
Wormian Bones	Not Expected	Not Expected	Expected	Not Expected	A,H,B vs. I
Canine Fossa	Expected	Expected	Not Expected	Not Expected	A,H vs. I,B
Inion Hook	Expected	Not Expected	Not Expected	Not Expected	A,H vs. I,B
Nasal Spine	Large	Small	Small	Small	A vs. H, I, B
Nasal Sill	Deep	Blurred	Blurred	Guttered	A vs. H, I vs. B
Nasion Depressed	Expected	Not Expected	Not Expected	Not Expected	A vs. H, I, B
Nasal Shape	Steepled	Tented	Tented	Quonset Hut	A vs. H, I vs. B
Slight Prognathism	Not Expected	Expected	Expected	Expected	A vs. H, I, B
Carabelli's Cusp	Expected	Not Expected	Not Expected	Not Expected	A vs. H, I, B
Molar Crenulation	Not Expected	Not Expected	Not Expected	Expected	A,H, I vs. B
Shoveled Incisors	Not Expected	Not Expected	Expected	Not Expected	A, H, B vs. I
Undulate Mandible	Undulate	Undulate	Rocker	Straight	A, H vs. I vs. B
Ascending Ramus	Slanted	Slanted	Vertical	Slanted	A,H,B vs. I
Oval Window	Expected	Expected	Not Expected	Expected	A,H,B vs. I
Zygomatico Suture	S-Shaped	Both Expected	Angled	S-Shaped	A, B vs. I
Venous Markings	Not Expected	Not Expected	Not Expected	Expected	A,H, I vs. B
Nasal Opening	Narrow	Medium	Wide	Wide	A vs. H vs. I, B

Table 8: Chi-Square Analyses for the Entire Mütter Museum Sample as Compared with Rhine's (1990) Expected Values

Variable	Anglo χ^2	Anglo P-Value	df	Hispanic χ^2	Hisp. P-Value	df	Indian χ^2	Indian P-Value	df	Black χ^2	Black P-Value	df
Metopism	6.804	**0.009***	1	314.197	<0.000	1	57.212	<0.000	1	57.212	<0.000	1
Wormian Bones	0.096	0.757	1	1.322	**0.250***	1	0.790	**0.374***	1	75.977	<0.000	1
Canine Fossa	28.332	**0.000***	1	0.855	**0.347***	1	5540942.8	<0.000	1	113.157	<0.000	1
Inion	2.823	0.093	1	14.341	<0.000	1	8.723	0.003	1	23.760	<0.000	1
Nasal Spine	65.677	**0.000***	1	71126010	<0.000	1	103.776	<0.000	1	103.776	<0.000	1
Nasion Depression	37.222	**0.000***	1	0.492	**0.483***	1	0.070	**0.792***	1	57.212	<0.000	1
Nasal Shape	0.251	0.616	1	52.466	<0.000	1	27560161	<0.000	1	27560161	<0.000	1
Slight Prognathism	60.340	**<0.000***	1	173.815	<0.000	1	36.111	<0.000	1	Error	Error	1
Carabelli's Cusp	7.176	**0.007***	1	54.810	<0.000	1	0.038	**0.845***	1	No results	No results	1
Ascending Ramus	16.257	**<0.000***	1	15.084	<0.000	1	174.905	<0.000	1	Error	Error	1
Oval Window	5.482	**0.019***	1	5.685	0.017	1	86.356	<0.000	1	2.146	**0.143***	1
Zygomatico Suture	7.779	**0.005***	1	13.817	<0.000	1	1.184	**0.276***	1	1.184	**0.276***	1
Venous Markings	31.912	**<0.000***	1	6.897	0.009	1	Error	Error	1	2.007	**0.157***	1
Nasal Opening	23.671	**<0.000***	2	344.437	<0.000	2	Error	Error	2	Error	Error	2

APPENDIX C

Chi-Square Results for Geographic Subgroups

Table 9: Chi-Square Analyses for the Geographic Groups Comparison for Austro-Hungary

Variable	The Balkans χ^2	The Balkans P-Value	df	The Baltics	The Baltics P-Value	df	Italian P. χ^2	Italian P. P-Value	df
Metopism	0.962	0.327	1	1.321	0.250	1	0.891	0.345	1
Wormian Bones	2.044	0.153	1	0.074	786	1	0.616	0.432	1
Canine Fossa	0.012	0.911	1	-	1.000^F	1	-	1.000^F	1
Inion Hook	1.122	0.290	1	0.933	0.334	1	0.877	0.349	1
Nasal Spine	0.812	0.367	1	-	1.000^F	1	0.407	0.523	1
Nasal Sill	34.110	**$<0.000^V$**	3	Error	Error	3	Error	Error	3
Nasion Depressed	0.002	0.963	1	4.223	**0.040***	1	0.891	0.345	1
Nasal Shape	0.086	0.769	1	0.278	0.598	1	0.036	0.849	1
Slight Prognathism	0.230	0.631	1	-	1.000^F	1	-	0.518^F	1
Carabelli's Cusp	0.839	0.360	1	0.104	0.747	1	0.151	0.697	1
Molar Crenulation	0.866	0.352	1	-	1.000^F	1	1.564	0.211	1
Shoveled Incisors	-	1.000^F	1	-	1.000^F	1	-	1.000^F	1
Undulate Mandible	6.116	**0.047***	2	Error	Error	2	2.279	0.320	2
Ascending Ramus	-	0.670^F	1	-	**0.050^{F*}**	1	-	1.000^F	1
Oval Window	2.494	0.114	1	-	1.000^F	1	6.514	**0.011***	1
Zygomatico Suture	0.047	0.829	1	-	0.533^F	1	0.174	0.677	1
Venous Markings	0.096	0.756	1	1.751	0.186	1	1.267	0.260	1
Nasal Opening	Error	Error	2	Error	Error	2	Error	Error	2

Table 10: Chi-Square Analyses for the Geographic Groups Comparison for The Balkans

Variable	Austro-Hungary χ^2	Austro-H P-Value	df	The Baltics χ^2	The Baltics P-Value	df	Italian P. χ^2	Italian P. P-Value	df
Metopism	0.962	0.327	1	-	1.000^F	1	3.057	0.080	1
Wormian Bones	2.044	0.153	1	-	0.173^F	1	-	**0.058^F**	1
Canine Fossa	0.012	0.911	1	-	1.000^F	1	-	1.000^F	1
Inion Hook	1.122	0.290	1	0.013	0.908	1	0.003	0.957	1
Nasal Spine	0.812	0.367	1	-	0.449^F	1	-	0.181^F	1
Nasal Sill	34.110	**$<0.000^V$**	3	15.081	**0.002^V**	3	17.368	**0.001^V**	3
Nasion Depressed	0.002	0.963	1	4.282	**0.039***	1	0.796	0.372	1
Nasal Shape	0.086	0.769	1	0.082	0.775	1	0.003	0.957	1
Slight Prognathism	0.230	0.631	1	-	0.702^F	1	-	0.307^F	1
Carabelli's Cusp	0.839	0.360	1	0.981	0.322	1	0.167	0.683	1
Molar Crenulation	0.866	0.352	1	-	1.000^F	1	0.156	0.693	1
Shoveled Incisors	-	1.000	1	-	1.000^F	1	-	1.000^F	1
Undulate Mandible	6.116	**0.047***	2	Error	Error	2	Error	Error	2
Ascending Ramus	-	0.670^F	1	-	0.176^F	1	-	1.000^F	1
Oval Window	2.494	0.14	1	-	0.178^F	1	1.342	0.247	1
Zygomatico Suture	0.047	0.829	1	0.243	0.622	1	0.053	0.817	1
Venous Markings	0.096	0.756	1	2.379	0.123	1	0.731	0.393	1
Nasal Opening	Error	Error	2	Error	Error	2	Error	Error	2

Table 11: Chi-Square Analyses for the Geographic Groups Comparison for The Baltics

Variable	Austro-Hungary χ^2	Austro-H P-Value	df	The Balkans χ^2	Balkans P-Value	df	Italian P. χ^2	Italian P. P-Value	df
Metopism	1.321	0.250	1	-	1.000^F	1	3.197	0.074	1
Wormian Bones	0.074	0.786	1	-	0.173^F	1	0.175	0.676	1
Canine Fossa	-	1.000^F	1	-	1.000^F	1	-	1.000^F	1
Inion Hook	0.933	0.334	1	0.013	0.908	1	0.003	0.955	1
Nasal Spine	-	1.000^F	1	-	0.449^F	1	-	0.723^F	1
Nasal Sill	Error	Error	3	15.081	**0.002^V**	3	0.726	0.867	3
Nasion Depressed	4.223	**0.040***	1	4.282	**0.039***	1	6.743	**0.009***	1
Nasal Shape	0.278	0.598	1	0.082	0.775	1	0.089	0.765	1
Slight Prognathism	-	1.000^F	1	-	0.702^F	1	-	0.698^F	1
Carabelli's Cusp	0.104	0.747	1	0.981	0.322	1	0.354	0.552	1
Molar Crenulation	-	1.000^F	1	-	1.000^F	1	-	0.683^F	1
Shoveled Incisors	-	1.000^F	1	-	1.000^F	1	-	1.000^F	1
Undulate Mandible	Error	Error	2	Error	Error	2	Error	Error	2
Ascending Ramus	-	**0.050^{F*}**	1	-	0.176^F	1	-	0.146^F	1
Oval Window	-	1.000^F	1	-	0.178^F	1	5.360	**0.021***	1
Zygomatico Suture	-	0.533^F	1	0.243	0.622	1	0.056	0.813	1
Venous Markings	1.751	0.186	1	2.379	0.123	1	4.359	0.037	1
Nasal Opening	Error	Error	2	Error	Error	2	Error	Error	2

Table 12: Chi-Square Analyses for the Geographic Groups Comparison for <u>The Italian Peninsula</u>

Variable	Austro-Hungary χ^2	Austro-H P-Value	df	The Balkans χ^2	Balkans P-Value	df	The Baltics χ^2	Baltics P-Value	df
Metopism	0.891	0.345	1	3.057	0.080	1	3.197	0.074	1
Wormian Bones	0.616	0.432	1	-	**0.058**^{F}	1	0.175	0.676	1
Canine Fossa	-	1.000^F	1	-	1.000^F	1	-	1.000^F	1
Inion Hook	0.877	0.349	1	0.003	0.957	1	0.003	0.955	1
Nasal Spine	0.407	0.523	1	-	0.181^F	1	-	0.723^F	1
Nasal Sill	Error	Error	3	17.368	**0.001**^{V}	3	0.726	0.867	3
Nasion Depressed	0.891	0.345	1	0.796	0.372	1	6.743	**0.009***	1
Nasal Shape	0.036	0.849	1	0.003	0.957	1	0.089	0.765	1
Slight Prognathism	-	0.518^F	1	-	0.307^F	1	-	0.698^F	1
Carabelli's Cusp	0.151	0.697	1	0.167	0.683	1	0.354	0.552	1
Molar Crenulation	1.564	0.211	1	0.156	0.693	1	-	0.683^F	1
Shoveled Incisors	-	1.000^F	1	-	1.000^F	1	-	1.000^F	1
Undulate Mandible	2.279	0.320	2	Error	Error	2	Error	Error	2
Ascending Ramus	-	1.000^F	1	-	1.000^F	1	-	0.146^F	1
Oval Window	6.514	**0.011***	1	1.342	0.247	1	5.360	**0.021***	1
Zygomatico Suture	0.174	0.677	1	0.053	0.817	1	0.056	0.813	1
Venous Markings	1.267	0.260	1	0.731	0.393	1	4.359	0.037	1
Nasal Opening	Error	Error	2	Error	Error	2	Error	Error	2

APPENDIX D

Chi-Square Results for Ethnolinguistic Subgroups

Table 13: Chi-Square Analyses for the Ethnolinguistic Groups
Comparison for <u>East Slavic Group</u>

Variable	German χ^2	German P-Value	df	West Slavic χ^2	West Slavic P-Value	df	South Slavic χ^2	South Slavic P-Value	df
Metopism	-	0.691^F	1	4.265	**0.039***	1	0.697	0.404	1
Wormian Bones	0.120	0.729	1	0.305	0.581	1	-	0.443^F	1
Canine Fossa	-	1.000^F	1	-	0.703^F	1	-	0.658^F	1
Inion Hook	0.450	0.502	1	-	0.735^F	1	0.030	0.862	1
Nasal Spine	-	0.691^F	1	-	1.000^F	1	-	0.180^F	1
Nasal Sill	3.174	0.366	3	Error	Error	3	18.958	$<0.00^V$	3
Nasion Depressed	4.5	**0.034***	1	-	0.669^F	1	3.747	**0.053**	1
Nasal Shape	3.010	0.083	1	0.000	1.000	1	0.274	0.600	1
Slight Prognathism	-	0.688^F	1	-	0.663^F	1	-	0.688^F	1
Carabelli's Cusp	-	0.473^F	1	3.939	**0.047***	1	2.778	0.096	1
Molar Crenulation	-	0.390^F	1	-	0.659^F	1	-	1.000^F	1
Shoveled Incisors	-	1.000^F	1	-	1.000^F	1	-	1.000^F	1
Undulate Mandible	1.755	0.416	2	Error	Error	2	3.206	0.201	2
Ascending Ramus	-	0.335^F	1	-	1.000^F	1	-	0.103^F	1
Oval Window	-	1.000^F	1	-	0.672^F	1	-	1.000^F	1
Zygomatico Suture	0.000	1.000	1	-	0.235^F	1	0.957	0.328	1
Venous Markings	3.273	0.070	1	-	0.132^F	1	-	0.264^F	1
Nasal Opening	Error	Error	2	Error	Error	2	Error	Error	2

Table 13 (cont'd)

Variable	Finno-Ugric χ^2	Finno-Ugric P-Value	df	Romance χ^2	Romance P-Value	df
Metopism	-	1.000^F	1	1.276	0.259	1
Wormian Bones	-	0.419^F	1	0.065	0.799	1
Canine Fossa	-	0.678^F	1	-	1.000^F	1
Inion Hook	0.814	0.367	1	0.744	0.388	1
Nasal Spine	-	0.461^F	1	0.018	0.893	1
Nasal Sill	3.438	0.329	3	2.242	0.524	3
Nasion Depressed	-	0.660^F	1	3.750	**0.053**	1
Nasal Shape	0.201	0.654	1	0.134	0.714	1
Slight Prognathism	-	1.000^F	1	-	1.000^F	1
Carabelli's Cusp	-	0.659^F	1	1.909	0.167	1
Molar Crenulation	-	0.149^F	1	-	0.714^F	1
Shoveled Incisors	-	0.450^F	1	-	1.000^F	1
Undulate Mandible	0.437	0.804	2	3.349	0.187	2
Ascending Ramus	-	0.613^F	1	-	0.655^F	1
Oval Window	-	1.000^F	1	1.667	0.197	1
Zygomatico Suture	-	0.249^F	1	0.847	0.357	1
Venous Markings	-	0.660^F	1	8.031	**0.005***	1
Nasal Opening	7.381	0.025^V	2	Error	Error	2

Table 14: Chi-Square Analyses for the Ethnolinguistic Groups Comparison for <u>West Slavic Group</u>

Variable	German χ^2	German P-Value	df	East Slavic χ^2	East Slavic P-Value	df	South Slavic χ^2	South Slavic P-Value	df
Metopism	7.619	**0.006***	1	4.265	**0.039***	1	1.642	0.200	1
Wormian Bones	0.051	0.821	1	0.305	0.581	1	-	0.233^{F}	1
Canine Fossa	-	0.703^{F}	1	-	0.703^{F}	1	-	0.370^{F}	1
Inion Hook	0.051	0.821	1	-	0.735^{F}	1	0.055	0.815	1
Nasal Spine	-	0.676^{F}	1	-	1.000^{F}	1	-	0.299^{F}	1
Nasal Sill	Error	Error	3	Error	Error	3	Error	Error	3
Nasion Depressed	1.499	0.221	1	-	0.669^{F}	1	1.106	0.293	1
Nasal Shape	-	0.142^{F}	1	0.000	1.000	1	0.241	0.623	1
Slight Prognathism	-	1.000^{F}	1	-	0.663^{F}	1	-	1.000^{F}	1
Carabelli's Cusp	-	0.427^{F}	1	3.939	**0.047***	1	-	1.000^{F}	1
Molar Crenulation	-	1.000^{F}	1	-	0.659^{F}	1	-	0.679^{F}	1
Shoveled Incisors	-	1.000^{F}	1	-	1.000^{F}	1	-	1.000^{F}	1
Undulate Mandible	0.068	0.967	2	Error	Error	2	0.051	0.975	2
Ascending Ramus	-	0.576^{F}	1	-	1.000^{F}	1	-	0.196^{F}	1
Oval Window	-	0.426^{F}	1	-	0.672^{F}	1	-	1.000^{F}	1
Zygomatico Suture	-	0.235^{F}	1	-	0.235^{F}	1	-	0.664^{F}	1
Venous Markings	0.008	0.928	1	-	0.132^{F}	1	0.185	0.667	1
Nasal Opening	Error	Error	2	Error	Error	2	Error	Error	2

Table 14 (cont'd)

Variable	Finno-Ugric χ^2	Finno-Ugric P-Value	df	Romance χ^2	Romance P-Value	df
Metopism	4.013	**0.045***	1	1.453	0.228	1
Wormian Bones	-	0.216^{F}	1	0.131	0.717	1
Canine Fossa	-	1.000^{F}	1	-	0.692^{F}	1
Inion Hook	1.474	0.225	1	1.513	0.219	1
Nasal Spine	-	0.411^{F}	1	-	1.000^{F}	1
Nasal Sill	5.019	0.170	3	1.061	0.787	3
Nasion Depressed	-	1.000^{F}	1	0.976	0.323	1
Nasal Shape	0.181	0.671	1	0.114	0.735	1
Slight Prognathism	-	0.645^{F}	1	-	0.690^{F}	1
Carabelli's Cusp	-	**0.030^{F*}**	1	-	0.470^{F}	1
Molar Crenulation	-	0.586^{F}	1	-	0.790^{F}	1
Shoveled Incisors	-	0.476^{F}	1	-	1.000^{F}	1
Undulate Mandible	3.970	0.137	2	0.863	0.649	2
Ascending Ramus	-	1.000^{F}	1	-	1.000^{F}	1
Oval Window	-	1.000^{F}	1	-	0.156^{F}	1
Zygomatico Suture	-	1.000^{F}	1	-	0.692^{F}	1
Venous Markings	-	0.429^{F}	1	0.997	0.318	1
Nasal Opening	Error	Error	2	Error	Error	2

Table 15: Chi-Square Analyses for the Ethnolinguistic Groups Comparison for South Slavic Group

Variable	German χ^2	German P-Value	df	East Slavic χ^2	East Slavic P-Value	df	West Slavic χ^2	West Slavic P-Value	df
Metopism	-	0.146^{f}	1	0.697	0.404	1	1.642	0.200	1
Wormian Bones	-	0.264^{f}	1	-	0.443^{F}	1	-	0.233^{F}	1
Canine Fossa	-	0.658^{f}	1	-	0.658^{F}	1	-	0.370^{F}	1
Inion Hook	0.238	0.625	1	0.030	0.862	1	0.055	0.815	1
Nasal Spine	-	0.604^{f}	1	-	0.180^{F}	1	-	0.299^{F}	1
Nasal Sill	20.905	**$<.000^{V}$**	3	18.958	$<0.00^{V}$	3	Error	Error	3
Nasion Depressed	0.030	0.862	1	3.747	**0.053**	1	1.106	0.293	1
Nasal Shape	1.457	0.227	1	0.274	0.600	1	0.241	0.623	1
Slight Prognathism	-	1.000^{f}	1	-	0.688^{F}	1	-	1.000^{F}	1
Carabelli's Cusp	0.621	0.431	1	2.778	0.096	1	-	1.000^{F}	1
Molar Crenulation	-	0.673^{f}	1	-	1.000^{F}	1	-	0.679^{F}	1
Shoveled Incisors	-	1.000^{f}	1	-	1.000^{F}	1	-	1.000^{F}	1
Undulate Mandible	Error	Error	2	3.206	0.201	2	0.051	0.975	2
Ascending Ramus	-	1.000^{f}	1	-	0.103^{F}	1	-	0.196^{F}	1
Oval Window	-	0.691^{f}	1	-	1.000^{F}	1	-	1.000^{F}	1
Zygomatico Suture	0.957	0.328	1	0.957	0.328	1	-	0.664^{F}	1
Venous Markings	0.305	0.581	1	-	0.264^{F}	1	0.185	0.667	1
Nasal Opening	Error	Error	2	Error	Error	2	Error	Error	2

Table 15 (cont'd)

Variable	Finno-Ugric χ^2	Finno-Ugric P-Value	df	Romance χ^2	Romance P-Value	df
Metopism	-	0.449 [f]	1	0.045	0.831	1
Wormian Bones	-	1.000 [f]	1	1.884	0.170	1
Canine Fossa	-	0.198 [f]	1	-	0.689 [f]	1
Inion Hook	1.094	0.296	1	1.075	0.300	1
Nasal Spine	-	**0.57** [f]	1	-	0.121 [f]	1
Nasal Sill	20.343	**<.000** [v]	3	14.696	**0.002** [v]	3
Nasion Depressed	-	0.273 [f]	1	0.029	0.865	1
Nasal Shape	-	1.000 [f]	1	0.045	0.831	1
Slight Prognathism	-	0.669 [f]	1	-	0.716 [f]	1
Carabelli's Cusp	-	**0.047** [f*]	1	0.290	0.591	1
Molar Crenulation	-	0.179 [f]	1	-	1.000 [f]	1
Shoveled Incisors	-	0.530 [f]	1	-	0.600 [f]	1
Undulate Mandible	Error	Error	2	Error	Error	2
Ascending Ramus	-	0.414 [f]	1	-	0.272 [f]	1
Oval Window	-	1.000 [f]	1	2.564	0.109	1
Zygomatico Suture	-	1.000 [f]	1	-	1.000 [f]	1
Venous Markings	-	0.694 [f]	1	2.397	0.122	1
Nasal Opening	17.961	**<.000** [v]	2	-	0.121 [f]	2

Table 16: Chi-Square Analyses for the Ethnolinguistic Groups Comparison for <u>Finno-Ugric Group</u>

Variable	German χ^2	German P-Value	df	East Slavic χ^2	East Slavic P-Value	df	West Slavic χ^2	West Slavic P-Value	df
Metopism	-	0.660^F	1	-	1.000^F	1	4.013	**0.045***	1
Wormian Bones	-	0.249^F	1	-	0.419^F	1	-	0.216^F	1
Canine Fossa	-	0.678^F	1	-	0.678^F	1	-	1.000^F	1
Inion Hook	2.222	0.136	1	0.814	0.367	1	1.474	0.225	1
Nasal Spine	-	0.210^F	1	-	0.461^F	1	-	0.411^F	1
Nasal Sill	Error	Error	3	3.438	0.329	3	5.019	0.170	3
Nasion Depressed	-	0.260^F	1	-	0.660^F	1	-	1.000^F	1
Nasal Shape	-	0.418^F	1	0.201	0.654	1	0.181	0.671	1
Slight Prognathism	-	0.669^F	1	-	1.000^F	1	-	0.645^F	1
Carabelli's Cusp	-	0.218^F	1	-	0.659^F	1	-	$\mathbf{0.030^{F*}}$	1
Molar Crenulation	-	0.604^F	1	-	0.149^F	1	-	0.586^F	1
Shoveled Incisors	-	0.476^F	1	-	0.450^F	1	-	0.476^F	1
Undulate Mandible	Error	Error	2	0.437	0.804	2	3.970	0.137	2
Ascending Ramus	-	1.000^F	1	-	0.613^F	1	-	1.000^F	1
Oval Window	-	0.669^F	1	-	1.000^F	1	-	1.000^F	1
Zygomatico Suture	-	0.249^F	1	-	0.249^F	1	-	1.000^F	1
Venous Markings	-	0.442^F	1	-	0.660^F	1	-	0.429^F	1
Nasal Opening	11.250	0.004^V	2	7.381	0.025^V	2	Error	Error	2

Table 16 (cont'd)

Variable	South Slavic χ^2	South Slavic P-Value	df	Romance χ^2	Romance P-Value	df
Metopism	-	0.449^{F}	1	-	0.305^{F}	1
Wormian Bones	-	1.000^{F}	1	-	0.276^{F}	1
Canine Fossa	-	0.198^{F}	1	-	0.416^{F}	1
Inion Hook	1.094	0.296	1	-	1.000^{F}	1
Nasal Spine	-	**0.570**^{F}	1	-	0.486^{F}	1
Nasal Sill	20.343	**<.000**^{V}	3	Error	Error	3
Nasion Depressed	-	0.273^{F}	1	-	0.305^{F}	1
Nasal Shape	-	1.000^{F}	1	0.026	0.872	1
Slight Prognathism	-	0.669^{F}	1	-	1.000^{F}	1
Carabelli's Cusp	-	**0.047**^{F*}	1	-	0.073^{F}	1
Molar Crenulation	-	0.179^{F}	1	-	0.210^{F}	1
Shoveled Incisors	-	0.530^{F}	1	-	0.368^{F}	1
Undulate Mandible	Error	Error	2	Error	Error	2
Ascending Ramus	-	0.414^{F}	1	-	1.000^{F}	1
Oval Window	-	1.000^{F}	1	-	0.269^{F}	1
Zygomatico Suture	-	1.000^{F}	1	-	0.693^{F}	1
Venous Markings	-	0.694^{F}	1	3.903	**0.048***	1
Nasal Opening	17.961	**<.000**^{V}	2	10.623	**0.005**^{V}	2

Table 17: Chi-Square Analyses for the Ethnolinguistic Groups Comparison for Romance Group

Variable	German χ^2	German P-Value	df	East Slavic χ^2	East Slavic P-Value	df	West Slavic χ^2	West Slavic P-Value	df
Metopism	3.750	**0.053**	1	1.276	0.259	1	1.453	0.228	1
Wormian Bones	0.016	0.900	1	0.065	0.799	1	0.131	0.717	1
Canine Fossa	-	1.000^F	1	-	1.000^F	1	-	0.692^F	1
Inion Hook	2.515	0.113	1	0.744	0.388	1	1.513	0.219	1
Nasal Spine	-	0.482^F	1	0.018	0.893	1	-	1.000^F	1
Nasal Sill	6.049	0.109	3	2.242	0.524	3	1.061	0.787	3
Nasion Depressed	0.134	0.714	1	3.750	**0.053**	1	0.976	0.323	1
Nasal Shape	2.328	0.127	1	0.134	0.714	1	0.114	0.735	1
Slight Prognathism	-	0.716^F	1	-	1.000^F	1	-	0.690^F	1
Carabelli's Cusp	0.125	0.724	1	1.909	0.167	1	-	0.470^F	1
Molar Crenulation	-	0.478^F	1	-	0.714^F	1	-	0.790^F	1
Shoveled Incisors	-	1.000^F	1	-	1.000^F	1	-	1.000^F	1
Undulate Mandible	Error	Error	2	3.349	0.187	2	0.863	0.649	2
Ascending Ramus	-	1.000^F	1	-	0.655^F	1	-	1.000^F	1
Oval Window	0.792	0.373	1	1.667	0.197	1	-	0.156^F	1
Zygomatico Suture	0.847	0.357	1	0.847	0.357	1	-	0.692^F	1
Venous Markings	0.952	0.329	1	8.031	**0.005***	1	0.997	0.318	1
Nasal Opening	Error	Error	2	Error	Error	2	Error	Error	2

Table 17 (cont'd)

Variable	South Slavic χ^2	South Slavic P-Value	df	Finno-Ugric χ^2	Finno-Ugric P-Value	df
Metopism	0.045	0.831	1	-	0.305^{F}	1
Wormian Bones	1.884	0.170	1	-	0.276^{F}	1
Canine Fossa	-	0.689^{f}	1	-	0.416^{F}	1
Inion Hook	1.075	0.300	1	-	1.000^{F}	1
Nasal Spine	-	0.121^{f}	1	-	0.486^{F}	1
Nasal Sill	14.696	**0.002**^{v}	3	Error	Error	3
Nasion Depressed	0.029	0.865	1	-	0.305^{F}	1
Nasal Shape	0.045	0.831	1	0.026	0.872	1
Slight Prognathism	-	0.716^{f}	1	-	1.000^{F}	1
Carabelli's Cusp	0.290	0.591	1	-	0.073^{F}	1
Molar Crenulation	-	1.000^{f}	1	-	0.210^{F}	1
Shoveled Incisors	-	0.600^{f}	1	-	0.368^{F}	1
Undulate Mandible	Error	Error	2	Error	Error	2
Ascending Ramus	-	0.272^{f}	1	-	1.000^{F}	1
Oval Window	2.564	0.109	1	-	0.269^{F}	1
Zygomatico Suture	-	1.000^{f}	1	-	0.693^{F}	1
Venous Markings	2.397	0.122	1	3.903	**0.048***	1
Nasal Opening	-	0.121^{f}	2	10.623	**0.005**^{V}	2

Table 18: Chi-Square Analyses for the Ethnolinguistic Groups Comparison for German Group

Variable	Romance χ^2	Romance P-Value	df	East Slavic χ^2	East Slavic P-Value	df	West Slavic χ^2	West Slavic P-Value	df
Metopism	3.750	**0.053**	1	-	0.691[F]	1	7.619	**0.006***	1
Wormian Bones	0.016	0.900	1	0.120	0.729	1	0.051	0.821	1
Canine Fossa	-	1.000[F]	1	-	1.000[F]	1	-	0.703[F]	1
Inion Hook	2.515	0.113	1	0.450	0.502	1	0.051	0.821	1
Nasal Spine	-	0.482[F]	1	-	0.691[F]	1	-	0.676[F]	1
Nasal Sill	6.049	0.109	3	3.174	0.366	3	Error	Error	3
Nasion Depressed	0.134	0.714	1	4.5	**0.034***	1	1.499	0.221	1
Nasal Shape	2.328	0.127	1	3.010	0.083	1	-	0.142[F]	1
Slight Prognathism	-	0.716[F]	1	-	0.688[F]	1	-	1.000[F]	1
Carabelli's Cusp	0.125	0.724	1	-	0.473[F]	1	-	0.427[F]	1
Molar Crenulation	-	0.478[F]	1	-	0.390[F]	1	-	1.000[F]	1
Shoveled Incisors	-	1.000[F]	1	-	1.000[F]	1	-	1.000[F]	1
Undulate Mandible	Error	Error	2	1.755	0.416	2	0.068	0.967	2
Ascending Ramus	-	1.000[F]	1	-	0.335[F]	1	-	0.576[F]	1
Oval Window	0.792	0.373	1	-	1.000[F]	1	-	0.426[F]	1
Zygomatico Suture	0.847	0.357	1	0.000	1.000	1	-	0.235[F]	1
Venous Markings	0.952	0.329	1	3.273	0.070	1	0.008	0.928	1
Nasal Opening	Error	Error	2	Error	Error	2	Error	Error	2

Table 18 (cont'd)

Variable	South Slavic χ^2	South Slavic P-Value	df	Finno-Ugric χ^2	Finno-Ugric P-Value	df
Metopism	-	0.146^{f}	1	-	0.660^{F}	1
Wormian Bones	-	0.264^{f}	1	-	0.249^{F}	1
Canine Fossa	-	0.658^{f}	1	-	0.678^{F}	1
Inion Hook	0.238	0.625	1	2.222	0.136	1
Nasal Spine	-	0.604^{f}	1	-	0.210^{F}	1
Nasal Sill	20.905	$\mathbf{<.000}^{V}$	3	0.864	0.649	3
Nasion Depressed	0.030	0.862	1	-	0.260^{F}	1
Nasal Shape	1.457	0.227	1	-	0.418^{F}	1
Slight Prognathism	-	1.000^{f}	1	-	0.669^{F}	1
Carabelli's Cusp	0.621	0.431	1	-	0.218^{F}	1
Molar Crenulation	-	0.673^{f}	1	-	0.604^{F}	1
Shoveled Incisors	-	1.000^{f}	1	-	0.476^{F}	1
Undulate Mandible	Error	Error	2	Error	Error	2
Ascending Ramus	-	1.000^{f}	1	-	1.000^{F}	1
Oval Window	-	0.691^{f}	1	-	0.669^{F}	1
Zygomatico Suture	0.957	0.328	1	-	0.249^{F}	1
Venous Markings	0.305	0.581	1	-	0.442^{F}	1
Nasal Opening	Error	Error	2	11.250	$\mathbf{0.004}^{V}$	2

APPENDIX E

Hierarchical Cluster Analyses of MMD Values

Cluster Analysis - Ethnolinguistic Grouping

Ward's Method - Mean Measure of Divergence

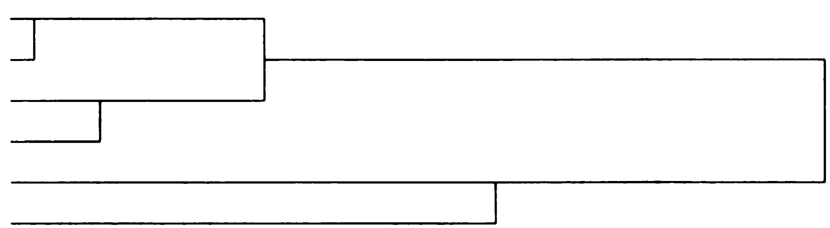
```
* * * * * * H I E R A R C H I C A L   C L U S T E R   A N A L Y S I S * * * * * *

 Dendrogram using Ward Method

                          Rescaled Distance Cluster Combine

         C A S E         0         5        10        15        20        25
  Label             Num  +---------+---------+---------+---------+---------+

  German Group        1
  West Slavic Group   3
  South Slavic Group  4
  Romance Group       6
  East Slavic Group   2
  Finno-Ugric Group   5
```



Cluster Analysis - Geographic Grouping

Ward's Method - Mean Measure of Divergence

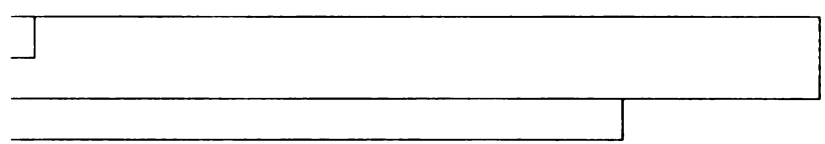
```
* * * * * * H I E R A R C H I C A L   C L U S T E R   A N A L Y S I S * * * * * *

 Dendrogram using Ward Method

                                    Rescaled Distance Cluster Combine

        C A S E                0         5        10        15        20        25
  Label                 Num   +---------+---------+---------+---------+---------+

  Austro-Hungary         1
  The Baltics            3
  The Balkans            2
  Italian Peninsula      4
```



LITERATURE CITED

LITERATURE CITED

Anonymous. 1979. Non-metric traits – Bibliography. *Journal of Human Evolution.* 8:705-708.

Angel JL and Kelley JO. 1990. "Inversion of the Posterior Edge of the Jaw Ramus: New Race Trait." In Skeletal Attributes of Race: Methods for forensic anthropology. Gill GW, and Rhine S. (eds.) Albuquerque, New Mexico: Maxwell Museum. pp. 33-40.

Ansorge H. 2001. Assessing non-metric skeleton characters as a morphological tool. *Zoology* 104:000-000.

Aubin MM. 2002. Nonmetric traits of the cervical vertebrae: Methods for data collection and comparison. American Association of Physical Anthropology 71st Annual Meeting. Poster presentation.

Barnett SA. 1970. The human species; a biology of man. Gloucester, MA: P. Smith.

Bass WM. 1995. Human Osteology: A laboratory and field manual of the human skeleton. Fourth edition. Columbia: Missouri Archaeological Society.

Benfer RA. 1970. Associations among cranial traits. *American Journal of Physical Anthropology* 32:463.

Bennett KA. 1965. The Etiology and genetics of wormian bones. *American Journal of Physical Anthropology* 23:255-260.

Berry AC. 1974. The Use of nonmetrical variations of the cranium in the study of Scandanavian population movements. *American Journal of Physical Anthropology* 40:345-358

Berry AC and Berry RJ. 1971. "Epigenetic polymorphism in the primate skeleton," in *Comparative Genetics in Monkeys, Apes and Man.* Edited by A.B. Chiarelli, pp. 13-42. New York: Academic.

Berry RJ. 1963. Epigenetic polymorphism in wild populations of *Mus musculus. Genetical Research* 4:193-220.

Birkby WH. 1973. *Discontinuous Non-metric Traits of the Skull as Population Markers in the Prehistoric Southwest.* Ph.D. Dissertation, University of Arizona.

Blakely RL. 1973. *Biological Variation Among and Between Two Prehistoric Indian Populations at Dickson Mounds.* Ph.D. Dissertation, University of Indiana.

Brace CL. 1995. Region does not mean "Race" – Reality versus convention in forensic anthropology. *Journal Forensic Science* 40:171-175.

Brace CL and Hunt KD. 1990. A nonracial craniofacial perspective on human variation: A(ustralia) to Z(uni). *American Journal of Physical Anthropology* 82:341-360.

Brooks S, Brooks RH, and France D. 1990. "Alveolar Prognathism Contour, an Aspect of Racial Identification." In <u>Skeletal Attributes of Race: Methods for forensic anthropology</u>. Gill GW, and Rhine S. (eds.) Albuquerque, New Mexico: Maxwell Museum. pp. 41-46.

Brues AM. 1990. The once and future diagnosis of race. In <u>Skeletal Attributes of Race: Methods for forensic anthropology</u>. Gill GW, and Rhine S. (eds.) Albuquerque, New Mexico: Maxwell Museum. pp. 1-7.

Buikstra JE. 1980. "Epigenetic distance: A study of biological variability in the lower Illinois river region," in *Early Native Americans*: *Prehistoric Demography, Economy, and Technology*. Edited by David L. Browman, pp. 271-299. New York: Mouton Publishers.

Buikstra JE, Frankenberg SR, and Konigsberg LW. 1990. Skeletal biological distance studies in American physical anthropology: Recent trends. *American Journal of Physical Anthropology* 82:1-8.

Buikstra JE, and Ubelaker DH. (eds.) 1994. <u>Standards for Data Collection from Human Skeletal Remains</u>. *Arkansas Archaeological Survey Research Series*. 44.

Busby A. 2002. Ontogenetic development of the axillary border of the scapula in Neanderthals. American Association of Physical Anthropology 71st Annual Meeting. Abstract.

Carpenter JC. 1984. A comparative study of metric and non-metric traits in a series of modern crania. *American Journal of Physical Anthropology* 45:337-344.

Cheverund JM, Buikstra JE, and Twitchell E. 1979. Relationships between non-metric skeletal traits and cranial size and shape. *American Journal of Physical Anthropology* 50:191-198.

Cheverud JM and Buikstra JE. 1978. A study of intragroup biological change induced by social group fission in *Macaca mulatta* using discrete cranial traits. *American Journal of Physical Anthropology* 48:41-46.

Cheverud JM and Buikstra JE. 1981. Quantitative genetics of skeletal nonmetric traits in the Rhesus macaques on Cayo Santiago. II. Phenotypic, genetic and environmental correlations between traits. *American Journal of Physical Anthropology* 54:51-58.

Cheverud JM and Buikstra JE. 1982. Quantitative genetics of skeletal nonmetric traits in the Rhesus macaques on Cayo Santiago. III. Relative heritability of skeletal nonmetric and metric traits. *American Journal of Physical Anthropology* 59:151-155.

Corruccini RS. 1974. An examination of the meaning of cranial discrete traits for human skeletal biological studies. *American Journal of Physical Anthropology*40:425-446.

Corruccini RS, Shimada I. 2002. Dental relatedness corresponding to mortuary patterning at Huaca Loro, Peru. *American Journal of Physical Anthropology* 117:113-121.

Cosseddu GG, Floris G, and Vona G. 1979. Sex and side differences in the minor non-metrical cranial variants. *Journal of Human Evolution* 8:685-692.

Cucina A, Tiesler Blos V, Sierra Sosa T. Dental anthropology, settlement pattern and social structure at the Maya site of Xcambo, Yucatan. American Association of Physical Anthropology 71st Annual Meeting. Abstract.

Czarnetzki A. 1975. On the question of correlation between the size of the epigenetic distance and the degree of allopatry in different populations. *Journal of Human Evolution* 4:483-489.

DeStefano GF, Hauser G, Guidotti A, Rossi S, Russo EG, and Gualandi PB. 1984. Reflections on interobserver differences in scoring non-metric cranial traits (with practical examples). *Journal of Human Evolution* 13:349-355.

Duray SM, Morter HB, and Smith FJ. 1999. Morphological variation in cervical spinous processes: potential applications in the forensic identification of race from the skeleton. *Journal Forensic Science* 44:937-944.

Duband A, Kidder J, and Jantz RL. 2002. A multivariate examination of the Hexian Homo erectus calvarium. American Association of Physical Anthropology 71st Annual Meeting. Abstract.

Eberly J. Nasal Index of Hyrtl Skull Collection. Unpublished study. Received from Worden G of the Mütter Museum of the College of Physicians of Philadelphia.

Federation of East European Family History Societies. 2001. FEEFHS Map Room – Background and Map Index. Electronic Document. http://feefhs.org/maps/indexmap.html, accessed February 18, 2002.

Finnegan M. 1974. Cranial and infracranial non-metric traits: those traits which are most important and how they may be handled. *American Journal of Physical Anthropology* 41:478-479 (abstract).

Finnegan M. 1978, An analysis of intra-observer error in non-metric studies. *American Journal of Physical Anthropology* 48:393 (abstract).

Finnegan M J and Cooprider K. 1978. Empirical comparison of distance equations using discrete trait. *American Journal of Physical Anthropology* 49:39-46.

Finnegan MJ and Faust MA. 1974. Bibliography of human and nonhuman nonmetric variation. Research Reports, 14. Department of Anthropology, University of Massachusetts, Amherst.

Finnegan M, and McGuire SA. 1979. Classification systems for discrete variables used in forensic anthropology. *American Journal of Physical Anthropology* 51:547-553.

Giles E, and Elliot O. 1962. Race Identification from Cranial Measurements. *Journal of Forensic Sciences* 7:147-56.

Gill GW. 1986. Craniofacial criteria in forensic race identification. In Forensic Osteology: Advances in the identification of human remains. Reichs KJ (ed.) Springfield, IL: Charles C. Thomas. pp. 143-159.

Gill GW, Hughes SS, Bennett SM, and Gilbert BM. 1988. Racial Identification from the midfacial skeleton with special reference to American Indians and Whites. *Journal of Forensic Sciences* 33:92-99.

Gill GW, and Rhine S. (eds.) 1990. Skeletal Attributes of Race: Methods for forensic anthropology. Albuquerque, New Mexico: Maxwell Museum.

Gill GW. 1995. Challenge on the frontier: Discerning American Indians from Whites Osteologically. *Journal of Forensic Sciences* 40:783-788.

Gill GW. 1998. Craniofacial criteria in the skeletal attribution of race. In Forensic Osteology: Advances in the identification of human remains. Reichs KJ (ed.) Springfield, IL: Charles C. Thomas. pp. 293-315

Green RF, and Suchey JM. 1976. The use of inverse sine transformations in the analysis of non-metric cranial data. *American Journal of Physical Anthropology* 45:61-68.

Griffin MC. 1989. Internet. *Dental Variation of Native Populations from Northern Spanish Florida.* M.A. Thesis. Department of Anthropology, Northern Illinois University, DeKalb. http://online.sfsu.edu/~mgriffin/mgthesis.html

Grüneberg H. 1952. Genetical studies on the skeleton of the mouse. IV. Quasi-continuous variations. *Journal of Genetics* 51:95-114.

Gualdi-Russo E, Tasca MA, and Brasili P. 1999. Scoring of nonmetric cranial traits: a methodological approach. *Journal of Anatomy* 195:543-550.

Hattman K. 2001. Morphological variability through ontogeny of the modern human chin. American Association of Physical Anthropology 70st Annual Meeting. Abstract.

Hauser G, and De Stefano GF. 1989. Epigenetic Variants of the Human Skull. Stuttgart: E. Schweizerbart'sche Verlagsbuchhandlung (Nägele u. Obermiller).

Heffner, JT. 2002. An assessment of craniofacial nonmetric traits currently used in the forensic determination of ancestry. American Academy of Forensic Sciences 54th Annual Meeting. Presentation.

Hennenberg RJ, De Migeul D, Castany J, Bernades J, Fabregas L, Calderer J, Townsend G, and Hennenberg M. Identical twins from the Neolithic Site Llord. American Association of Physical Anthropology 70st Annual Meeting. Abstract.

Hinkes MJ. 1990. Shovel shaped incisors in human identification. In Skeletal Attributes of Race: Methods for forensic anthropology. Gill GW, and Rhine S. (eds.) Albuquerque, New Mexico: Maxwell Museum. pp. 21-26.

Hooton, EA. 1920. Peabody Museum of Harvard University - Cranial Observations and Indices. In Skeletal Attributes of Race: Methods for forensic anthropology. Gill GW, and Rhine S. (eds.) Albuquerque, New Mexico: Maxwell Museum. pp. 3-4.

Hooton, EA. 1930. The Indians of Pecos Pueblo. New Haven: Yale University.

Howells. 1995. Who's Who in Skulls: Ethnic identification of crania from measurements. Papers of the Peabody Museum of Archaeology and Ethnology. Vol. 82. Cambridge, MA: Harvard.

Hunley KL and Cabana GS. 2001. One or many species? A method for comparing Middle Pleistocene and modern human morphological variation. American Association of Physical Anthropology 70st Annual Meeting. Abstract.

Imber CE and Aiello LC. 2001. Postcranial robusticity and rugosity patterning in modern humans. American Association of Physical Anthropology 70st Annual Meeting. Abstract.

Jantz RL, and Jantz LM. 2000. Secular change in craniofacial morphology. *American Journal of Human Biology* 12:327-338.

Kelso, AJ. 1970. Physical anthropology; an introduction. Philadelphia: Lippincott. pp. 94.

Kemper MJ. 1970. Whatever happened to Joseph Hyrtl? M.A. Thesis. Temple University.

Kennedy B. 1981. Marriage patterns in an archaic population: A study of skeletal remains from Port au Choix, Newfoundland. *Archaeological Survey of Canada, National Museum of Man, Mercury Series, Paper No. 104.*

Kennedy KAR. 1995. But Professor, why teach race identification if races don't exist? *Journal Forensic Science* 40:797-800.

Korey KA. 1970. *Characteristics of the Distributions of Non-metric Variants of the Skull.* M.A. Thesis, University of Chicago, Illinois.

Lane RA and Sublett AJ. 1972. Osteology of social organization: Residence pattern. *American Antiquity* 37:186-201.

Lane RA. 1978. Non-metric osteological variation as a function of genetic kinship. *American Journal of Physical Anthropology* 48:413 (abstract).

Larsen CS. 1997. Bioarchaeology: Interpreting behavior from the human skeleton. Cambridge: Cambridge University Press. pp. 302-332.

Livingstone FB. 1964. On the non-existence of human races. In The Concept of Race. Montagu, A. (ed.) New York: The Free Press of Glencoe. pp. 46-60.

Lovejoy CO, Meindl RS, Pryzbeck TR, Mensforth RP. 1985. Chronological Metamorphosis of the Auricular Surface of the Ilium: A new method for the determination of adult skeletal age at death. *American Journal of Physical Anthropology* 68:15-28.

Lovejoy CO, Reno PL, Kriz MA, Rosenman BA. 2002. Developmental field fluctuation: a potential basis for skeletal morphological variation. American Association of Physical Anthropology 71st Annual Meeting. Abstract.

Molto JE. 1979. The assessment and meaning of intraobserver error in population studies based on discontinuous cranial traits. *American Journal of Physical Anthropology* 51:333-344.

Moore-Jansen PM, Ousely SD, and Jantz RL. 1994. Data Collection Procedures for Forensic Skeletal Material. Report of Investigations No. 48 Department of Anthropology, University of Tennessee, Knoxville.

Napoli ML, and Birkby WH. 1990. Racial differences in the visibility of the oval window in the middle ear. In Skeletal attributes of race: Methods for forensic anthropology. Gill GW, and Rhine S. (eds.) Albuquerque, New Mexico: Maxwell Museum. pp. 27-32.

Nystom KC. 2002. Ethnicity and the ancestors: A bioarchaeological investigation of ethnic boundaries. American Association of Physical Anthropology 71st Annual Meeting. Abstract.

Ossenberg NS. 1969. *Discontinuous Morphological Variation in the Human Cranium.* Ph.D. Thesis, University of Toronto.

Ossenberg NS. 1970. The influence of artificial deformation on discontinuous morphological traits. *American Journal of Physical Anthropology* 33:357-372.

Ossenberg NS. 1977. Congruence of distance matrices based on cranial discrete traits, cranial measurements, and linguistic-geographic criteria in five Alaskan populations. *American Journal of Physical Anthropology* 47:93-98.

Ousley S, and Billeck W. 2001. Assessing tribal identity in the plains using nontraditional craniometrics (interlandmark distances). Presented at the 70th Annual Meeting of the American Association of Physical Anthropologists, Kansas City, MO. March 28-31.

Perizonius WRK. 1979. Non-metric cranial traits: Sex difference and Age Dependence. *Journal of Human Evolution* 8:679-684.

Phenice TW 1969. A newly developed visual method of sexing the os pubis. *American Journal of Physical Anthropology* 30:297-302.

Powell JF, Neves WA. 1999. Craniofacial morphology of the first Americans: Pattern and process in the peopling of the New World. *American Journal of Physical Anthropology* 110:153-188.

Praymak RC, Graver AM, Parr RL, Molto JE. 2001. A heritability study of the non-metric trait fronto-temporal articulation in the Dakhleh Oasis, Egypt using mitochondrial DNA analysis. . American Association of Physical Anthropology 70st Annual Meeting. Abstract

Rhine S. 1990. Non-metric skull racing. In Skeletal Attributes of Race: Methods for forensic anthropology. Gill GW, and Rhine S. (eds.) Albuquerque, New Mexico: Maxwell Museum. pp. 9-20.

Richtsmeier JT and McGrath JW. 1986. Quantitative genetics of cranial nonmetric traits in randombred mice: heritability and etiology. *American Journal of Physical Anthropology* 69:51-58.

Sauer NJ. 1992. Forensic anthropology and the concept of race: If races don't exist, why are forensic anthropologists so good at identifying them? *Social Science and Medicine* 34:107-111.

Saunders SR and Popovich F. 1978. A family study of two skeletal variants: Atlas bridging and clinoid bridging. *American Journal of Physical Anthropology* 49:193-204.

Schwartz JH. 1995. Skeleton Keys: An introduction to human skeletal morphology, development, and analysis. New York: Oxford University Press. pp. 257-291.

Shepherd FJ. 1893. Symmetrical Depressions on the Exterior Surface of the Parietal Bones. *Journal of Anatomy and Physiology* 27:501-504.

Simmons T, and Lagrou MK. 2001. Age indicators are population specific – Caution! American Academy of Forensic Sciences Proceedings, Vol. 7.

SPSS. 1999. Statistical Package for Social Sciences, version 10.0. Chicago: SPSS, Inc.

Steadman DW. 2001. Mississippians in motion? A population genetic analysis of interregional gene flow in west-central Illinois. *American Journal of Physical Anthropology* 114:61-73.

Stefan VH. 1999. Craniometric variation and homogeneity in prehistoric/protohistoric Rapa Nui (Easter Island) regional populations. *American Journal of Physical Anthropology* 110:407-419.

Steininger, C. 2002. Variation in the face of *Australopithecus robustus*. American Association of Physical Anthropology 71st Annual Meeting. Abstract.

Suchey JM, Wisely DV, and Katz D. 1986. Evaluation of the Todd and McKern-Stewart methods of aging the male *Os pubis*. In Forensic Osteology: Advances in the identification of human remains Reichs, K (ed.). Springfield, IL: Thomas. Pp. 33-67.

Sugar P and Treadgold R. 1993. Historical Atlas of East Central Europe. University of Toronto Press.

Symmers WSC. 1895. A skull with enormous parietal foramina. *Journal of Anatomy and Physiology* 29:329-330.

Thomas CL (ed.). 1997. Taber's Cyclopedic Medical Dictionary. 18th ed. Philadelphia: F.A. Davis Company. pp. 1269.

Ubelaker DH. 1997. Latest developments in skeletal biology and forensic anthropology. In Biological Anthropology: The state of the science. Boaz NT, and Wolfe LD. (eds.) Second ed. Corvalis, OR: Oregon State University. pp. 101-115.

Ullinger J and Sheridan SC. 2001. "Let us go to the house of the Lord": Biocultural reconstruction of pilgrimage. American Association of Physical Anthropology 70st Annual Meeting. Abstract.

Ullinger J. 2002. A dental reconstruction of biological relationships in the Late Bronze and Early Iron Ages of the Southern Levant. American Association of Physical Anthropology 71st Annual Meeting. Abstract.

Villmoare B. 2001. Randomization method to analyze variation in non-metric characters, and the single species concept for Homo erectus. American Association of Physical Anthropology 70st Annual Meeting. Abstract.

Weiss E. 2002. The mystery of muscle markers: Aggregation and construct validity. American Association of Physical Anthropology 71st Annual Meeting. Poster Presentaiton.

Worden G. 1995. The Hyrtl Skull Collection. Transactions & studies of the College of Physicians of Philadelphia.

Wrobel GD. 2002. Intertrait association: measuring correlations among dental discrete traits within and between tooth classes in a Maya skeletal collection. American Association of Physical Anthropology 71st Annual Meeting. Abstract.