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BIOLOGICAL RELATIONSHIPS OF SIX
WESTERN EUROPEAN POPULATIONS

BIOLOGICAL DIVERGENCE BETWEEN
SIX WESTERN EUROPEAN POPULATIONS
AS DETERMINED BY NON-METRICAL CRANIAL VARIANTS

By

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A Thesis

Submitted to the School of Graduate Studies
in Partial Fulfilment of the Requirements

for the Degree

Master of Arts

McMaster University

September, 1975

DEDICATION

for

T.

MASTER OF ARTS (1975)
(Anthropology)

McMASTER UNIVERSITY
Hamilton, Ontario

TITLE: Biological Divergence Between Six Western European
Populations as Determined by Non-Metrical Cranial
Variants

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NUMBER OF PAGES: x, 161

ABSTRACT

This study seeks to establish the extent of biological divergence between six populations who have, at various times, inhabited Western Europe: Gauls, Franks, Burgundians, Merovingians, Carolingians, and Basques. Biological divergence is determined using an established methodology for examining and recording the various states of expression of non-metrical, morphological, cranial variants. Being under genetical mediation, an analysis of the distribution of these variants using a mean square 'distance' statistic supplies estimates of the extent of biological divergence between any pair of populations being considered.

Based upon historical sources several hypotheses may be drawn concerning the degrees of relatedness of these six populations. Because of the purported northern European ancestry of the Gauls, Franks, and Burgondes, a strong genetical similarity may be expected between them. Further, it would be expected that the Franks and Gauls show more similarities to each other than the Burgondes with either the Franks or Gauls, based upon the common territory shared by the two former groups.

The Merovingians and Carolingians are said to be dynasties of Frankish kings and so would be expected to strongly

resemble the Franks, while it may be foreseen that the Franks and Merovingians are more genetically similar than are the Franks and Carolingians, the Merovingians being closer chronologically and having absorbed fewer non-Frankish peoples than the Carolingians.

Finally the Basques, considered to be of non-northern European origin, would be expected to show stronger affinity for the Frankish Merovingians and Carolingians than for the three northern European populations.

In order to test these hypotheses samples of skeletal material representing each of the six populations were drawn from the collection housed at the Musée de l'Homme, Paris, and the frequencies of 40 non-metrical cranial traits were recorded. Null hypotheses for sex and side-by-side correlation with the incidence of non-metrical cranial variants were also tested.

It was found that hypotheses concerning the degrees of relatedness between these six populations were in general upheld by the biological data: the Basques were found to be roughly twice as close genetically to the Merovingians and Carolingians as they were to the northern European peoples; the genetical 'distance' between the Burgondes and Franks and Burgondes and Gauls was found to be one and one-half times greater than that between the Gauls and Franks; the

Merovingians were found to be 25% closer to the Franks than were the Carolingians, and the degree of relatedness between the Merovingians and Carolingians was found to be greater than that between either of those groups and the ancestral Franks. Finally, side-by-side and sex correlation were found to be absent or at a very low level. Discussion of these findings and suggestions for methodological improvements are offered.

ACKNOWLEDGEMENTS

During all stages of this research many persons and institutions were called upon for aid, cooperation, and advice. Each came through in turn and I wish to offer my most sincere appreciation and thanks: for financial aid, in the form of travel grants and field support, I am indebted to Dr. E.V. Glanville, Chairperson, Department of Anthropology, McMaster University, the School of Graduate Studies, McMaster University, and my parents Dr. and Mrs. S.H. Sternberg; for opening the doors and collections of the Laboratoire d'Anthropologie, Musée de l'Homme, I thank its director, Dr. R. Gessain; for giving me a home in the field and thereby making my work there so much more pleasant I deeply thank M. and Mme. G. Paisnel; to Dr. G. Gaherty goes my most sincere appreciation for inspiring, guiding, and encouraging me through the planning and field-work stages of this research; to my Committee for their patience, advice, and cooperation my appreciation and thanks; and finally to my good friends, who put up with my waspishness during the dark moments, thank you.

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CHAPTER 1

INTRODUCTION

(I) Research Problem

The goal of this study is the determination of the extent of biological divergence between Gaul, Frank, Burgundian, Merovingian, Carolingian, and Basque populations, as represented by samples of their skeletal remains. Of concern here is whether these six populations may be considered a homogenous group, or whether the populations, distinguished historically, temporally, and geographically, may also be distinguished biologically. The thesis then is centred on the question, 'To what degree do these ethnic units equal biological units?'

The determination of biological divergence is achieved through the use of discrete, non-metrical, morphological variation of the cranium. The frequency of the various states of expression of forty non-metrical cranial traits have been recorded for series of crania representing each of the six populations. These frequencies of genetically mediated variants, when analyzed with a mean square 'distance' statistic, yield a figure representing the estimate of biological

divergence between any pair of populations, and thus the affinities of each population vis-a-vis every other population may be judged.

This study represents the first attempt at an analysis of the biological affinities of the Gauls, Franks, Burgondes, Merovingians, Carolingians, and Basques, though others (for example Morant 1939) have examined one or more of these populations using standard anthropometric methodology.

Being the first study of its kind this thesis uses hypotheses of biological affinity predicated upon historical data, and seeks to test the validity of those hypotheses. Thus as well as discovering the extent of biological autonomy possessed by each population, this investigation identifies the differences between the traditional view of the relationships between these peoples and those relationships as evidenced by the biological data.

In addition to testing hypotheses of biological affinity, this study examines the nature of the correlation between the incidence of non-metrical traits and such factors as age, sex, etc. This is done because the multivariable statistical analysis performed (Chapter 4) requires that the frequencies of non-metrical variants be uncorrelated with such factors, or if correlated, that some corrective measures be taken to insure the validity of results obtained from the statistical analysis.

At the core of any study which attempts to establish the degree of relatedness between human populations lies the concept of variation, and in this study, the concept of non-metrical, morphological, cranial variation. In the following sections of this chapter these concepts are outlined and discussed.

(II) Human Variation

One of the principal goals of physical anthropology is "the understanding of human variation" (Howells 1943:357); its range, nature, and extent among living and dead human populations, its possible significance, and the evolutionary mechanisms responsible for it.

The nature of human variation is much the same as variation in other species, namely that:

. . . like other animal species, (man is) both polymorphic and polytypic. That is . . . individuals are highly variable in any place, and the average of individuals also differs from place to place (Howells 1967:269).

This intraspecific variation offers a distinct advantage for survival at the species level, as Gaherty (1970) has noted, for natural variation forms the grist for the mill with which the evolutionary process, through natural selection, proceeds.

The study of human variation has undergone two great changes in the past century. Firstly, the great cataloguing works (for example Bateson 1894) gave way to the works of such men as Chambellan (1883) and Russel (1900). The former was the first to suggest the use of polymorphisms as anthropological characters, while the latter was the first to compare diverse populations in terms of those characters. Sullivan

(1922) used polymorphisms to study American crania and concluded that anatomical variants paralleled craniometric characters in frequency and distribution, and that high frequencies of a particular trait occur in groups located close to one another, while frequency decreases with geographical distance from that population.

Secondly the realization grew that morphological variation, and its underlying polygenic variation, must be studied in view of the dynamic qualities of human populations. Workers such as Boas (1891, 1892, and 1895), Russel (1900), and Sullivan (1922) treated populations as static physical entities, and their typological similarities and differences were interpreted to reflect affinities. Cybulski (1972:3) has quite correctly stated that this "concept of typology . . . (is) inconsistent with our current state of knowledge about physical variation."

The perception of human populations as dynamic elements within a biological framework replaces typological thinking with the potential for genetical and morphological change through time and space, and the concept that:

The morphology of a group is not based on a cluster of similar characteristics found on its constituent members and so defining a physical type, but in the relative incidence of features within the group forming a population profile (Anderson 1968a:60, emphasis in the original).

Thus, modern comparative population studies utilizing variation have two aspects: 1. the morphological and underlying genetical variation of individuals within populations, and 2. the perception of populations as dynamic entities. Using this theoretical background, the incidence of various polymorphisms may be compared, and statements made concerning the relationships of two or more populations.

The first great body of literature using this new approach to comparative population studies was based upon work done with living groups using such polymorphisms as blood groups and serums, red-green color-blindness, and dermatoglyphics. As Jantz (1970) points out, this preference for living groups and these polymorphisms was at least partially due to the known mode of inheritance of the variants involved, as well as the availability of demographic, genealogical, and cultural data. Jantz (1970:1) notes as well, however, that "the only direct avenue for temporal studies of human groups lies in their skeletal remains."

There are two methodological approaches to the inter-populational study of skeletal variation. An analysis of metrical variation utilizes measures whose plotted observed values describe a continuous curve, while one using non-metrical variants employs measures whose observed values fall into discrete, discontinuous categories. This distinction is, however, not always valid as some traits, for example

tubercles, are recorded on a continuous scale and later reduced to a discontinuous scale to permit chi-squared analysis (see Chapter 4). For this reason a more valid distinction may be drawn in which a metrical analysis reaches its conclusions based upon continuous data, while a non-metrical analysis bases its conclusions upon discontinuous data.

For this investigation non-metrical variation of the cranium was chosen as the vehicle with which to analyze the biological affinities of six populations.

(III) Non-Metrical Cranial Variation

The use of non-metrical variation in conjunction with a multivariate statistical analysis was first introduced by Laughlin and Jørgensen (1956) in their study of the biological affinities of four Greenlandic Eskimo isolates, and this methodology has since been widely used.

One element involved in the widespread adoption of this methodology is a general dissatisfaction with anthropometry for judging population affinities. This dissatisfaction may be attributed to: 1. the time-consuming nature of measurements; 2. the fact that good anthropometric data may only be obtained from fairly well preserved material; 3. the difficulty in applying multivariate statistics to metrical data owing to their high sex, age, and inter-trait correlation; 4. the belief that discontinuous traits tend to

be monogenic whereas continuous ones are polygenic, and that continuous ones therefore have a more complicated mode of inheritance, and 5. that continuous traits are more prone to environmental influence.

This general dissatisfaction is perhaps best expressed by Boyd's (1950:22) statement that:

. . . the conventional measurements were, and to a large extent still are, taken with little regard for what is known of embryology, centres of ossification, etc. Thus the whole elaborate structure of anthropometry was never really consistent with its own basic assumptions, and was destined ultimately to collapse of its own weight.

Several authors have pointed out, however, that the criticisms of anthropometry on genetical grounds are not necessarily well-founded. Brothwell (1963) warns that it is not clear whether the variation in metrical traits is monogenic or polygenic, and Wilkinson (1971) has cautioned that it is unwise to assume that traits treated as discontinuous are more simply inherited than continuous ones, for as little is known of the genetics of one as of the other.

In terms of the application of metrical and non-metrical variation to population affinity problems, several studies (for example Rightmire 1972; Jantz 1970; DeVilliers 1968) have found that:

. . . cranial measurements properly treated in multivariate statistical fashion, provide at least as much information (as non-metrical traits) useful to the study of population movement and past history (Rightmire 1972:274).

The use of non-metrical variants for the study of population affinities is predicated upon the same principle as the use of metrical traits, namely that:

. . . morphological similarities and differences which are genetical in nature will present patterns of interrelationship which will approximate genetical patterns among such populations (Cybulski 1972:5).

In other words, the variation in the incidence of variants between populations is genetically mediated, and "closely related populations resemble each other in the incidence (of variants), while less related groups show significant differences" (Anderson 1968b:135).

The reasons for the widespread usage of non-metrical variants may be summarized as, 1. they are quick and easy to observe and record; 2. significant, useful data may be obtained from fragmented material, including the osteological remains of cremation; 3. in mature individuals the virtual absence of sex, age, or inter-trait correlation, and in the case of bilateral traits the absence of side correlation, allows the use of simplified multivariate statistics; 4. the use of non-metrical data and multivariate statistics has

often been found to supply better estimates of divergence between populations than metrical data, and 5. the variants are apparently overwhelmingly genetical in nature, are relatively stable in various environmental conditions, and sensitively reflect differences between closely related populations.

Discontinuous data are quicker and easier to observe and record than continuous data as in most cases their absence or presence is apparent, and with increasing standardization of observations (see Chapter 3), this author feels that a lower inter-observer error may be expected with non-metrical variants.

It has been shown by several workers (for example Merbs 1967) that complete, well-preserved material is not necessary for the retrieval of useful non-metrical data, and that indeed this methodology is especially useful when dealing with groups who practiced cremation of the dead.

Because a multivariable statistic may be validly used only when all variables vary independently, the nature of significant sex, age, side, and inter-trait correlations in mature individuals has been investigated extensively.

Side Correlation

Nearly all investigators have found a virtual absence of positive correlation between right and left sides in

bilaterally occurring variants (for example Gaherty 1970; Finnegan 1973a; Ossenberg 1969; Berry and Berry 1967, 1971). In consequence of this lack of correlation, these workers have pooled the right and left sides in the case of potentially bilateral traits. Noting that although this practice is justified, Kellock and Parsons (1970a), Parsons and Howe (1967), and Howe and Parsons (1968) caution that the pooling of sides may supply only an approximation since individuals are usually more symmetrical for bilateral traits than would be expected by chance alone.

Torgersen (1951a) has stated that when small significant side differences are found to be influencing the incidence of traits it is probably due to a slight retardation of ossification on the right side, and that this retardation is associated with cerebral hemisphere dominance and vascular supply.

Age Correlation

Investigation of the possible age-dependency of non-metrical variants led Ossenberg (1970) to conclude that the small amounts of such dependency encountered would not alter the significance of the genetical distance calculated. These small correlations she attributed to the supposition that non-metrical variations are the end-points of competing developmental processes which occur during the life-time and vary from trait to trait and individual to individual.

Berry and Berry (1967) and Knip (1971) found no age dependency, while Finnegan (1973) has suggested that the slight age-regressive nature of some traits (see Chapter 3) is not enough to necessitate a correction before application of a multivariate statistic, unless the combined populations produce a distinctly bimodal age-curve. Korey (1970) and Buikstra (1972) both maintain, however, that the possibility of age-dependency must be examined before a multivariate statistic is applied to the data.

Sex Correlation

The sex-dependency of discrete traits has been found to be slight or absent by Berry and Berry (1967, 1971), Berry *et al.* (1967a) and Corruccini (1972), among others. Several authors (for example Gaherty 1970; Jantz 1970) have, however, found it quite prevalent and have attempted to explain and deal with the problems it raises.

Gaherty (1970) reported sexually dependent traits to be those whose dimorphism can be attributed to the characteristically heavier buttressing and more powerful musculature of the male skeleton, while Ossenberg (1970) found the same situation and concluded that the influence of sex on non-metrical variants is the same as on other morphological features, namely that females tend to retain more infantile characteristics than males.

Several methods of dealing with sexually dimorphic traits have been proposed in the literature. Finnegan (1972) has suggested that using equal numbers of males and females corrects for frequency differences between the two sexes caused by dimorphism, while Gaherty (1973) believes that male and female data should be summed for traits not showing sex-dependency, and male data alone used for traits that do show such dependency. This approach is in part predicated upon the assumption that males display population differences more strongly than do females. Gaherty (1970) believes further that when all skeletal material is sexed using the same anthroposcopic critieria, it can be logically assumed that the best preserved material will be most accurately sexed, and that the examination for possible sex-dependency of traits is best done on this best preserved, and most accurately sexed, material. Therefore in this study the Basque sample is used for detecting possible sex dimorphism (see Chapter 5).

Jantz (1970) recommends that sex-dependent variants be handled by eliminating them from the traits used to calculate biological distance. Finnegan (1972) and Kellock and Parsons (1970a) have shown through principle components analysis, however, that those traits which show sex-dependency also account for the greatest per cent of variance between populations. To discard these traits, as Jantz suggests, would

therefore "exclude the traits that best distinguish and define the affinities between populations in question" (Finnegan 1973:10).

Inter-Trait Correlation

The last possible correlation to be considered is between individual non-metrical variants themselves. Several workers (for example Kellock and Parsons 1970a; Ossenberg 1969; Knip 1971; Berry and Berry 1967) have found independent variation of all non-metrical traits in man, and Truslove (1961) reported the same for variants of the mouse skeleton. Ossenberg (1970:357) concludes that:

. . . correlation in pairs of the minor variants is generally either absent or at a very low level.

It should be noted that several of these 'very low level' correlations have been reported between some variants. Comas (1942) and Ashley-Montagu (1933) found significant correlations between metopism, epipteritic bones, and fronto-temporal articulation. Other variants which have been found to have significant correlations include parietal foramina and ossicles (Hess 1946), parietal foramina and emissary veins (Padget 1956; O'Rahilly and Twohig 1952), and parietal foramina and sagittal wormian bones (Padget 1956).

Hertzog (1968) reported significant positive correla-

tions among seven cranial characters, and found that those traits positively associated were located in the same regions of the skull. He noted that these patterns of regional associations were heritable, and that their frequencies were constant within strains. Hertzog's findings, however, have been refuted by Benfer (1970), who worked with the former's data and found no significant positive association between any of the seven cranial variants concerned.

The foregoing discussion of the possible positive correlations between non-metrical variants and sex, age, side, and other non-metrical traits has indicated that although the majority of these traits are usually not significantly associated with any of these variables, they may, at times, show such correlation. Therefore it seems that Finnegan's (1973a:2) advice is wise to follow:

. . . each sample must be first tested for sex, side, and possibly age differences before the statistical analysis of genetic distance coefficients be performed.

The literature dealing with the genetical nature of non-metrical variation is voluminous, and reflects the fact that our knowledge in this area is derived chiefly from work with non-human species, for example inbred mice (Grüneberg 1963), wild mice (Weber 1950; Deol 1958; Harland 1958; Searle 1960; Berry 1963), rats (Grüneberg 1961), guinea pigs (Berry and Searle 1963), and cats and dogs (Searle 1960). As Berry and

Berry (1967) have pointed out the extrapolation to human genetics is not without hazard. There is, however, no evidence to suppose that the genetical basis is much different in man (Knip 1971), and human family and population studies indicate that for many variants the mode of inheritance is similar in non-humans and humans (Berry et al. 1967a).

Only since the demonstration of the genetical control of non-metrical variation (chiefly by Grünberg) have these traits become a respectable means for determining the biological affinities of non-living populations, and this work has resulted in the following conclusions:

1. For any one trait each strain has a characteristic frequency (Grünberg 1952; Searle 1954a), and that frequency is similar in related strains (Berry and Berry 1967).

Familial studies (for example Ashley-Montagu 1937; Torgersen 1951b; Selby et al. 1955; Grahnén 1962; Suzuki and Sakai 1960; Johnson et al. 1965) have shown specific non-metrical traits (for example metopism, bridging of first cervical vertebra, agenesis of teeth, and the torii palatinus and mandibularis) to be inherited, usually as a dominant gene with incomplete penetrance, and just as for blood-group frequencies, isoincidence lines can be drawn for variant incidences (Brothwell 1959). Grünberg (1952) cautions, however, that it is the incidence of a trait in a population that is inherited, not its segregation in a family.

2. The entity inherited is not the presence or absence of a trait, but rather the size, or rate of development, of an embryonic rudiment. Grünberg (1951) showed that agenesis of the third molar in mice was caused by an inherited factor of tooth bud size, not mature tooth loss, and that if the tooth germ is too small the tooth fails to develop. Body weight of mice at 60 days has been found to parallel differences in the incidences of non-metrical skeletal variants, suggesting an association between the incidence of traits and the size of structures which are correlated with body weight (Howe and Parsons 1967).

Therefore a threshold mechanism (Grewal 1962a) is involved which divides the continuous distribution of a trait into discrete phenotypes, and this threshold is imposed at a stage of embryonic development such that embryonic rudiments above or below the critical size develop alternate phenotypes.

3. The existence for each variant of several frequency levels in different, presumably pure, strains, and the incidence of each variant in F_1 and F_2 generations of crosses between strains indicates several gene loci are involved in variant inheritance (Kellock and Parsons 1970b).

4. Mutational events change the characteristic frequency of a trait in a strain (Grünberg 1955).

5. Within an inbred strain, factors of maternal physiology such as diet, maternal age, and litter size, may

influence trait incidence (Deol and Truslove 1957; Green 1941; Berry and Searle 1963; Searle 1954a, and b). Differences produced by these factors, however, are at a lower level than those produced by genetic factors (Berry 1963), and though maternal factors may influence individual trait frequency, the environment is of little import when data on a large number of traits is combined to analyze populational affinities (Howe and Parsons 1967).

Thus the genetical mediation of non-metrical variation may be seen as comprising, 1. the underlying continuous variable influenced by the action of several genes, and 2. the discontinuity imposed during the embryonic development by an inherited threshold mechanism.

Grüneberg (1952) has called this process "quasi-continuous" variation and has called the discontinuity imposed by the existence of alternative possible results of development the "epigenetic" consequence of the interaction or competition between different developmental processes. Berry and Searle (1963), noting that discontinuous variation should be distinguished from true genetical polymorphism, call the process "epigenetic polymorphism".

It would thus appear that non-metrical traits are an expression of genes affecting the process of development, and that therefore differences in frequencies of traits between populations reflects genetical differences in those

populations. Further there are few correlations between these traits so that frequency differences between populations can be summed and used as a measure of divergence between pairs of populations.

Using this methodology many workers have attempted to demonstrate and explain the biological affinities of extinct human populations, and several would agree with Ossenberg's (1969:34) conclusion that non-metrical variation supplies:

. . . possibly the best evidence for assessing biological affinity among extinct human populations.

Berry and Searle (1963) have stated that frequency differences of non-metrical variants within a species could be indicative of microevolutionary change, and thus the variants could be used (Berry 1963, 1964) to assess relationships between populations including deductions about the movement of populations. Brothwell (1965:14), examining several extinct British populations, concluded that:

In view of the successive waves of intrusive groups into Britain during the past 4,000 years, it seems reasonable to interpret the differences in these epigenetic characters as being due to changes in the gene pool as a result of the immigrants.

Gaherty (1974:15) found that "discrete traits. . . are still more valuable than cranial measurements" in assessing the

biological relationships of African populations, while Finnegan (1972) found the frequency of non-metrical variants, lexicostatistics, and radio-carbon data for North-west Coast populations highly correlated.

It would seem then, that although the exact genetical nature of non-metrical variation in man is not yet known, the knowledge so far accumulated strongly suggests that variants are inherited and points to the conclusion that:

This variation is inherited, although it is actually by developmental (epigenetic) thresholds, rather than by straight-forward gene action (Berry and Berry 1967:377).

Given this, non-metrical variation offers a very useful additional parameter for the study of both ancient and recent human populations.

Cranial and Infra-Cranial Variation

In this study non-metrical variation of the cranium was used to determine biological divergence. This decision was entirely dictated by the fact that the osteological collection of the Laboratoire d'Anthropologie, Musée de l'Homme is virtually devoid of large series of post-cranial remains or mandibles, while it is conspicuously rich in extensive series of crania.

Finnegan (1973) found that divergence estimates obtained

with cranial and infra-cranial data correlated very highly ($r = .906$; $p > .01$), and stated (1973a) that fewer significant differences are found in infra-cranial data than in cranial data from the same population.

It would seem then that non-metrical variation of the cranium is as good, or slightly better, a distinguisher of populations as infra-cranial variation.

CHAPTER 2

The Populations

(I) The Skeletal Series

All of the skeletal materials studied in the course of this investigation are part of the collection housed at the Laboratoire d'Anthropologie, Musée de l'Homme, Paris. Each specimen in the collection is identified with a catalogue number and these are in turn indexed in a card file. This file provides the following information for each specimen in most, though not all, cases: description of the specimen, provenience, date of discovery and/or cataloguing, source, and a population designation for the specimen. The data on these cards were relied upon when assembling the cranial series used in this study.

A specimen was automatically excluded from consideration if its provenience or population designation were unavailable. This population designation was in all cases used to identify the skeletal material. For example, all material herein considered to be Burgonde is so considered because 'Burgonde' appeared on the index card.

This practice places blind trust in the data in the file, for in no case do they indicate by what criteria a

population designation is assigned to a particular specimen. It is assumed that sound archaeological criteria were employed.

The data on specimen provenience were likewise accepted as accurate. For populations which were represented by specimens from many geographical areas, an effort was made to choose those clustered in one such region, and where possible the entire sample of a population was drawn from one location (for example Basques and Merovingians). Table 2.1 lists the provenience of skeletal material for each population and provides the number of specimens drawn from each site.

Figure 2.1 plots the provenience of samples on a map of northwestern Europe. The number of sites listed in Table 2.1 and those plotted in Figure 2.1 do not correspond because sites in close proximity to one another are represented by one point on the map.

With the explicit assumption that the skeletal series herein studied are indeed samples of the peoples to which they are attributed by the index files, it remains to analyze what those samples are, or might be, and how they may be understood within the context of the population chronology. This is necessary since in no case are data available to indicate where the skeletal samples fit within the chronology of their respective populations. The samples thus 'float' in time and we must speculate as to their positions, given

TABLE 2.1

Provenience of Samples and Number of Specimens Drawn Therefrom*

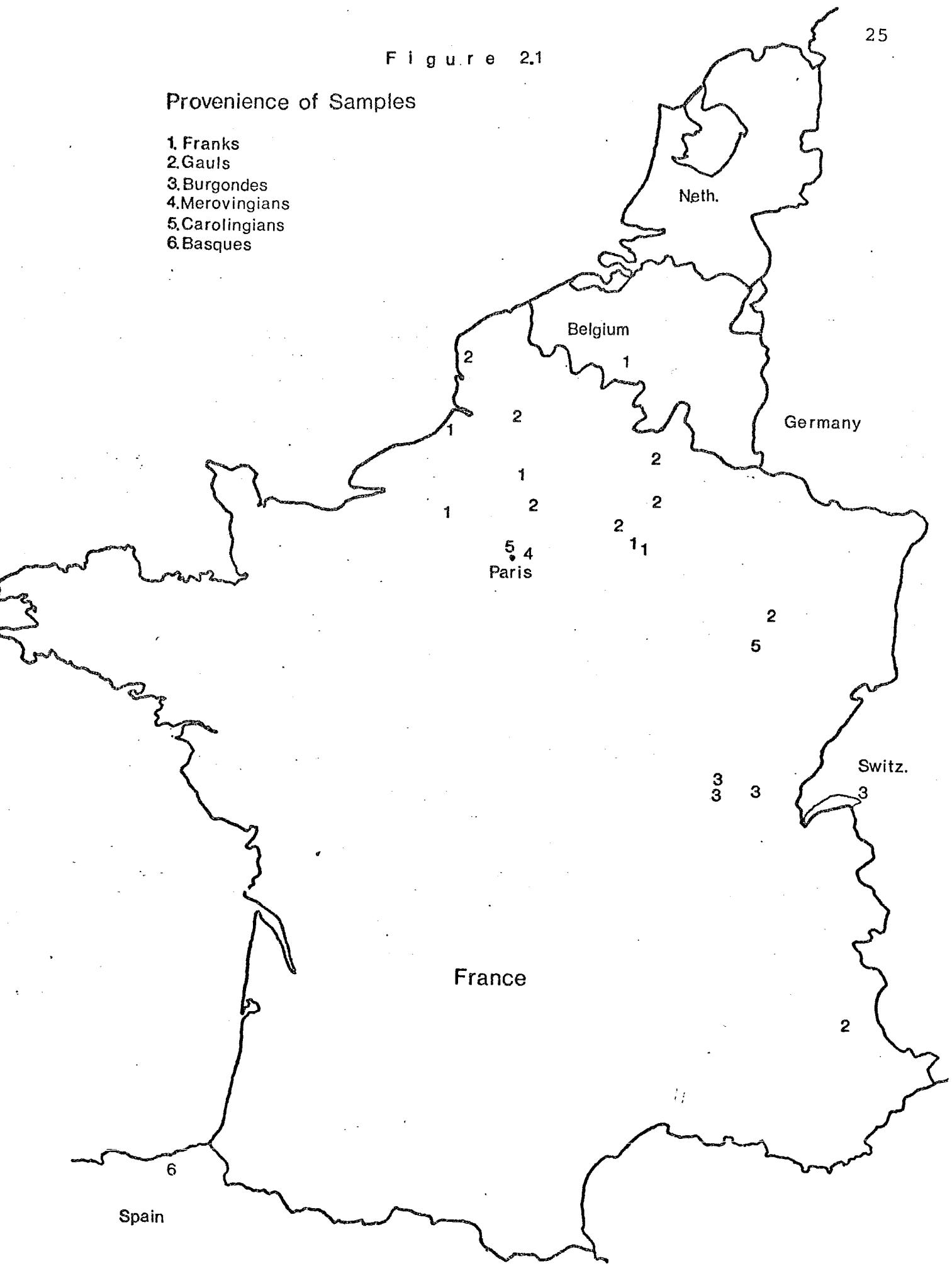
Gauls:	Mareuil-le-port, Marne (7) Nogent-les-vierges, près Creil, Oise (10) St. Ouen à Noyelle, Somme (4) de Palsy, commune de Pommiers, Aisne (2) Conantray, Marne (6) Boulogne-sur-Mer, Pas-de-Calais (2) Contréxéville, Haute-Marne (10) Barcellonette, Basses Alpes (2) Marne (unspecified) (20)
Franks:	Muids, Eure (27) Bassin Parisien (2) Bergères-les-Vertus, Marne (16) Normée, Marne (16) Eu, Seine inferiòr (1) Harmignies, Belgium (2)
Burgondes:	Vingire, Ain (4) Remasse, Ain (5) Genthoud, Canton de Genève, Switz. (1) Cret de Savière pres Mesigny (1) Lacrost (2) Beauregard-Tournus (2) Dulphey (2) Farges les Macône (6)
Merovingians:	Chelles, Oise (46)
Carolingians:	Luxeuil, Haute Saône (3) Paris Cemeteries (unspecified) (24) St. Marcel Cemetery, Paris (11) St. Etienne du Mont Cemetery, Paris (16)
Basques:	Zaraus, Guipuscoa, Spain (28)

*Note: unless otherwise noted all sites are within modern France.

Figure 2.1

Provenience of Samples

1. Franks
2. Gauls
3. Burgondes
4. Merovingians
5. Carolingians
6. Basques



the recorded histories of each population and the geographical provenience of the samples.

In Table 2.2 the temporal parameters and geographical limits of the samples, and the probable ethnic origins of the population represented, are shown.

The samples of Gauls, all from eastern France, probably postdate the fourth century B.C. for it was not until after this date that the Gauls left their southwest German homeland to cross into France. The Romans, under Julius Caesar, subjugated France and its inhabitants in 51 B.C. and made of it the province of Gaul, and it is therefore this date which is given as the probable upper-limit of the Gaul samples. The Musée de l'Homme file distinguishes 'Gauls' of pre-Roman Western Europe, and 'Gallo-Romans' of Roman Gaul. Only the former were considered in this study. It is, of course, entirely possible that burials identifiable as Gaulish were made after the Roman occupation. In addition, especially in north and central Gaul, the Roman presence was weak owing to its being confined to upper-strata administrative posts (Geipel 1969; Coon 1939). Therefore the Roman genetic influence in Gaul may be assumed to have been extremely limited as well.

The samples of Franks, which with one Belgian exception are from northern France, most probably postdate 300 A.D. for two reasons. Firstly, the Frankish incursions

SAMPLE POPULATION DESIGNATION	TEMPORAL PARAMETERS OF SAMPLE	GEOGRAPHICAL LIMITS OF SAMPLES	PROBABLE ETHNIC ORIGIN OF POPULATION
Gaul	4-300 - 58-51 B.C.	Northeastern France	Northern European
Frank	300 - 481 A.D.	Northern France - Southcentral Belgium	Northern European
Burgundian	443 - 534 A.D. (?)	Eastcentral France - Western Switzerland	Northern European
Merovingian	481 - 751 A.D.	Northcentral France	Frank
Carolingian	751 - 887 A.D.	Northcentral - Northeastern France	Merovingian
Basque	modern	Western Pyrenees, Spain	aboriginal (Alpine?) (Mediterranean?)

Sample Parameters

TABLE 2.2

into Roman Gaul did not commence in earnest until after 300 A.D., and secondly, Todd (1972) reports that only after 300 A.D. did interment replace cremation among the Franks as the dominant mode for dealing with the dead. As our samples are uncremated, and recovered from sites within France, 300 A.D. is a reasonable lower-limit to the Frankish samples.

The upper-limit to the Frankish samples is given as 481 A.D. for it was in that year that Clovis I consolidated the Frankish people under his rule and founded the Merovingian dynasty. It is assumed that clear archaeological criteria were used in differentiating pre-Merovingian Franks from Merovingian Franks so that 481 A.D. serves as a reasonable estimate of the upper-limit of the Frank samples.

The Burgundian samples are from the Savoy region (near Lake Geneva) of both France and Switzerland. These samples must postdate 443 A.D. for in that year Rome relocated the defeated Burgondes in that area of Gaul. Though this first kingdom of Burgundy was conquered by the Merovingians in 534 A.D., the samples may derive from a later date. Not until 1477 A.D., under the reign of Louis XI, did Burgundy cease to be politically independent, so that skeletal material for that area might, from 433 until 1477 A.D., be rightfully labeled 'Burgonde'. Not knowing the criteria for designation, it is not possible to discern where within the thousand-year history of independent Burgundy the samples fall. The

Burgondes who settled Savoy in 433 A.D. were a northern European people, purportedly originating on the Isle of Bornholm and that part of the north German coast opposite this island (Schütte 1929).

By definition the Merovingian sample should fall within the years 481-751 A.D., for these dates mark the accession of Clovis I, first Merovingian king, and that of Pepin the Short, first Carolingian king, respectively. 'Merovingian' however is normally considered to be a political term, designating the first dynasty of Frankish kings:

Merovingian, as we call it, or Merowing, as the Franks called it, was not only a family name, but sometimes the name of a people. All the Franks without distinction were called the Merowings, for the name of Merowig, an ancient chief whom all the members of the nation venerated as their common ancestor (Thierry 1845:98).

Thus 'Merovingian' may be regarded as a term which purportedly has no biological significance.

The Carolingian sample should postdate the crowning of Pepin the Short (751 A.D.) and antedate the deposition of the last Carolingian king (887 A.D.). As with 'Merovingian', 'Carolingian' has been regarded as a political term used to designate the second dynasty of Frankish kings. The Carolingians were thus descendants of the Merovingians, and through them, the pre-Merovingian Franks.

The Basque sample, derived from the western Spanish Pyrenees, is presumed to be modern. Part of the Broca Collection at the Laboratoire d'Anthropologie, which was assembled in the late 1800's, the Basque sample is notable for its virtually pristine condition. This exceptionally fine state of preservation, in contrast to the other samples, and the fact that the Basques continue to be an identifiable population lead to the presumption that the Basque sample is a modern one.

The Basques are aboriginal to the western Pyrenees in that they have been reported in that area since Roman times. Though there is some dispute as to their origins (see for example Grant 1922; Coon 1939; Fleure 1925; and Morant 1939), there is no doubt that their origins do not lie in the northern European stock that gave rise to the Franks, Gauls, and Burgundians.

(II) Population Affinities

This summation will address itself to the question: based upon the preceding accounts what may be expected to be the general outlines of biological affinity between these six populations?

Of the six peoples three are considered to be of northern European ancestry (Gauls, Franks, and Burgondes), two of

Frankish descent (Merovingians and Carolingians), and one, the Basques, of non-northern European stock. Thus, in general, one may expect the Basques to show greater genetical affinity for the Frankish descended Merovingians and Carolingians than for the northern European Gauls, Franks, and Burgundians. This relationship may be foreseen on the basis of chronology (i.e., the Basque sample being closer chronologically to the Merovingians and Carolingians than to any of the other three populations), and the presumption that the Merovingians and Carolingians, being further removed from their northern European ancestors, may therefore be expected to have lost, through microevolutionary processes, some of their distinction from non-northern European peoples, in this case the Basques.

Concerning the three populations of northern European origin, one may envision a closer affinity between the Gauls and Franks than between the Burgondes and either of those groups. This is based on the common western European territory inhabited by the Gauls and Franks after circa 300 A.D.

Both the Merovingians and Carolingians are descendants, or stages, of the Franks and so may be expected to display a close affinity for that ancestral population. The Merovingians would be expected to be the more 'Frankish' of the two, being earlier and not having absorbed as many other peoples

as the empire-building Carolingians. The Merovingians and Carolingians themselves should be closely aligned, sharing common ancestors and being in immediate chronological sequence.

It is against these general predictions that the results of this study will be compared and differences discussed in chapter 5. There remains, however, one additional question to be addressed: as an analysis of biological divergence depends upon the existence and maintenance of the idiosyncratic genotype of each sample, what factors might have influenced the preservation of genetic individuality among these six populations?

Genotypic identity in a population is maintained through reproductive isolation, and in the course of the 'Wandering of the Peoples', through which the Gauls, Franks, and Burgondes entered their new western European homes, there can be little doubt that the constant and very extensive migrations of the northern European peoples served to obscure, to some degree, their genetical identities. These migrations, coupled with inter-marriage, the capture of women, the taking of slaves, etc., have led some (for example Huxley and Haddon 1935; Geipel 1969) to presume that following the 'Wandering of the Peoples' the names 'Gaul', 'Frank', and 'Burgonde' had no biological meaning. One of the goals of this thesis is to confirm or disprove that very presumption.

CHAPTER 3

NON-METRIC CHARACTERS

(I) Introduction

In this chapter the 40 non-metric characters of the cranium used in this study are defined, aetiologies discussed, and previous findings cited. Though not in any way exhaustive, the following does serve to explain the variants and show their place in the literature and in non-metric cranial analysis.

Several lists or catalogues of non-metric cranial traits have been published, for instance Wood-Jones (1930-31), Berry and Berry (1967), and DeVilliers (1968). This study has used traits selected, and where noted modified from, the University of Toronto codification form for osteological analysis.

This catalogue, rather than another, was selected for the ease with which it permits data to be prepared for electronic computer analysis (see Chapter 4). The University of Toronto system, however, merely supplies the researcher with a list of traits and a systematized method for recording the data derived from observing those traits in their various states of expression. It is incumbent

upon any user of the system to define the traits listed therein.

Finnegan (1973a) has observed that data derived from non-metric analysis is usually ego-centric, that is the data is considered unusable by other workers owing to the lack of precise trait definition. This confusion may range from such gross variants as the presence or absence of the inca bone, to such fine details as the presence or absence of the Vesalian foramen.

This lack of standardization has been a great handicap to the field. The work of Comas (1960) and others has provided basic definitions and standardizations in anthropometry which have allowed workers to borrow and utilize each others data, knowing that this data was arrived at using an accepted technique of measurement. In non-metric analysis, however, little sharing and/or utilization of other's data is possible owing to the imprecision and/or lack of definition. This handicap has curtailed non-metric analysis by requiring each researcher to rely upon his own data for basic analysis.

It is therefore hoped that the following defines the traits used here with sufficient detail and precision to allow this data, and/or these traits, to be readily used and understood by other investigators.

The traits selected for use from the University of Toronto system were chosen on the basis of, 1) their demonstrable frequency differences among diverse populations, and 2) that these frequency differences are at least partially attributable to a genetic and heritable mode of control.

(II) Cranial Morphology

Metopism (sutura frontalis s. metopica)

Metopism, the retention of the foetal or infantile form of the frontal bone (Sullivan 1922; Ossenberg 1970), is the result of a failure of union between the two halves of the frontal bone. This union usually begins in the second year and is completed by the eighth (Gray's Anatomy 1962), though Oetteking (1930), Berry and Berry (1967), and Brothwell (1963) report completion by the end of the second year of life, and Limson (1924) by the fourth to sixth year.

The phenotypic result of an unfused frontal bone is the persistance of the medio-frontal, or metopic, suture which when complete divides the frontal bone from the nasion to the bregma (DeVilliers 1968). According to DeVilliers (1968:82) the complete metopic suture is typically:

...dentate, the edges of the two bones being finely serrated from nasion to a point some two centimeters anterior to the coronal suture when its course becomes simple and direct. The simple portion is the area included within the anterior fontanelle.

The suture need not persist over its entire foetal course, however, and traces of it may be observed (Limson 1924) usually as a linear remnant at the nasion (DeVilliers 1968; Sullivan 1922). Oetteking (1930) considered these traces as being of three distinct types: nasal triangle, pars nasalis, and pars supraglabellaris, and noted that while full metopic suture retention was rare in North Pacific coast crania (2-3%), retention of traces of that suture were frequent. Sullivan (1922) noted as well the rarity of full metopism and the relative frequency of nasion-to-glabella trace retention in Eskimo crania. In this study full and trace retention have been noted, however Oetteking's (1930) designation of three trace types has not been used.

The aetiology of metopism has long been under study. Sullivan (1922:255) concluded that metopism:

...may often arise secondarily. (Its) sporadic and limited distribution would ...seem to indicate this and eliminate (it) as a racial characteristic, although... with opportunities for distribution (it) might become secondarily a racial characteristic.

Oetteking (1930) surmised that due to its near non-existence in anthropoids, its rarity in 'primitive' varieties of man, and its increase in frequency among ancient and modern cultures, metopism was not of phylogenetic origin but rather was the result of an expanding fore-brain.

Ashley-Montagu (1937) was the first to posit genes for metopism and non-metopism, and Hess (1945) saw it as part of a genetically controlled metopic 'syndrome'. Torgersen (1951b), based upon a familial study of Norwegians, found the persisting metopic suture to be inherited as a dominant trait with varying degrees of penetrance and the obliteration of that suture due to a homozygous, recessive allele.

Frequencies of metopism in diverse populations are also well documented. Le Double (1903) found an average frequency of 8.2% for the white 'race', while Martin (1914) reported an average of 8.7% in Europeans. Sullivan (1922) showed the high variability of the trait even within small geographical areas with his study of Bolivian crania, and Comas (1942) and Ashley-Montagu (1937) provided frequencies for the trait in many populations. Akabori (1933) found none in 413 modern Japanese crania.

The degree of correlation between metopism and other traits, as well as sex and age, has also been widely reported. Sullivan (1922) found no significant correlation

between metopism and inca bone, tympanic dehiscence, lambdoid ossicles or artificial cranial deformation. Oetteking (1930) found metopism most frequent in short and broadheaded people, while Ashley-Montagu (1937) reported it in conjunction with frontal breadth, Woo (1949) with frontal curvature, and Stallworthy (1932) associated it with parietal foramina and irregular coronal suture synostosis.

Comas (1942) correlated metopism with epipteritic bones (21.1% in metopics versus 11.6% in non-metopics), bregmatic bones (1.4% versus 0.39%), and with the 'I' and 'K' forms of pterionic articulation rather than the 'H' form.

Ossenberg (1970) classified metopism as a hypostotic trait caused either by insufficiency of ossification or arrested morphogenesis, noted a female priority for the trait, and found it to be somewhat age-regressive to a certain point beyond which stabilization of frequency occurred.

Frontal Grooves (incisurae frontalis)

Frontal grooves are bilateral, or unilateral (Ossenberg 1970), paths running from either the supraorbital notch/foramen or from an inferiorly located foramen where some branches of the supraorbital nerve enter the bone, to the coronal suture. They may, on occasion, not reach as far as that suture but they never cross it to lie on the parietal bone (Dixon 1900).

When present they accommodate the supraorbital vessels and nerve (Anderson 1963; Dixon 1900), and usually occur beneath the outer branches of that nerve though they may occur beneath the inner branches as well (Dixon 1900). In any case they run medial to the temporal line (Cybulski 1973), and Dixon (1900) has noted that the grooves are sometimes covered with a thin roof of bone, making them into tunnels.

Dixon (1900:96) believed their aetiology lay in:

... a want of proportion between the growth in length of the nerves and the amount of expansion of the underlying part of the cranium.

He felt that the nerves and vessels acted as constricting cords which became pressed into the expanding frontal bone due to the excessive development of that bone or the insufficient growth of the nerves and vessels (Dixon 1904). Ossenberg (1970) is of the same mind, namely, that the grooves are the result of a growth differential between the nerves and vessels and the bone they cross. She believes that this same differential accounts, as well, for the variation in supraorbital features (see below).

Dixon (1900) reported this trait as rare in Australians, Tasmanians, and Melanesians, seldom seen in Polynesians, and very common (50%) in Zulus and "Kaffirs".

Akabori (1933) recorded its frequency in modern Japanese crania as 55% (male) and 34% (female). Cybulski (1973) noted its presence in ten of twenty-four sides of Northwest coast Indians, and drew attention to its absence in four adult males and its bilateral presence in three adult females and one juvenile.

Akabori (1933) found the trait to be age-stable with a slight preference for males and the right side, and Ossenberg (1970) agrees with Akabori and classifies the grooves as hyperostotic, that is, resulting from excessive ossific activity.

Brow Shape

The brow shape is dependent upon the presence, to some degree, of the supraorbital ridges whose shapes have been classified as discontinuous (the glabella not involved), straight (the ridges form straight lines on either side of the glabella which again is not involved), or 'V'-shaped (the ridges form a 'V' shape with the glabella involved as the inferior angle).

Wright and Anderson (1963), Anderson (1968a) and Melbye (1969) have all used this classification in population studies and have found the 'V'-shape to be the mode in Iroquois crania.

Brow Rugosity

The supraorbital ridges may be absent or present and if the latter, may range in development from slight to well-marked. This trait is sexually dimorphic with males showing characteristically more massive ridges than females (Krogman 1962; Brothwell 1963; Bass 1971).

Ossenberg (1970) includes brow ridges as one of the hyperostotic features that differentiate the sexes, while Anderson (1962a) has noted the utility of this trait in the determination of population affinities.

Supraorbital foramen and notch (foramen et incisura supraorbitalis)

In this study the supraorbital foramina and notches were observed along the entire supraorbital margin, that is the usual distinction between supraorbital and supratrochlear features was not made.

This distinction was not made owing to the considerable confusion that may arise when distinguishing supraorbital, supratrochlear, and frontal foramina and/or notches, though the latter trait was not used in this study. Anderson (1962a) has drawn attention to the variable position of the supraorbital foramen and/or notch in relation to other bony landmarks thus questioning DeVilliers' (1968) precise definition of its location, and Melbye (1969) has pointed out the

complications of dividing supraorbital from supratrochlear foramina and/or notches. In order to avoid this confusion and the element of subjectivity that must be introduced in order to differentiate supraorbital from supratrochlear features, this study has scored all notches and/or foramina on the supraorbital margin without attempting a distinction.

In life the supraorbital and supratrochlear nerves, both branches of the frontal nerve, and the supraorbital and supratrochlear arteries, branches of the ophthalmic artery, pass across the supraorbital margin to gain access to the roof of the orbit (Oetteking 1930; Gray's Anatomy 1962). Both nerves supply the conjunctiva and upper eyelid, and the supratrochlear supplies the lower parts of the forehead close to the median line, while the supraorbital innervates the scalp skin to the lambdoid suture (Gray's Anatomy 1962). Both arteries supply the skin, muscles, and pericranium of the forehead and anastomose with one another (Gray's Anatomy 1962).

These nerves and vessels may pass over the supraorbital margin in single or multiple foramina, single or multiple notches, in combinations of the above symmetrically or asymmetrically arranged, or simply over the smooth bone without notch or foramen. This latter possibility, the so-called 'pithecoid' pattern (Yamaguchi 1967) is, however, very rare (Oetteking 1930).

The aetiology of this variation seems to lie in what Dixon (1900) and Ossenberg (1970) have called a growth differential between the nerves and vessels and the underlying frontal bone. Bennett and Hulse (1966) found the frequency of foramina to be basically genetic in origin, and Ossenberg (1970) believes, after Dixon (1900), that the genetic control is over this possible growth differential.

The variability and distribution of these variants has long been recorded. Le Double (1906) could find no racial differences in frequencies of occurrence, while Wood-Jones mentions their racial variability but does not supply any data (1930-31).

Oetteking (1930) concluded that the notch is the more primitive feature as it is found in fossil Hominidae and in 'primitive' living races. In his North Pacific coast crania he found the notch predominant in young crania and postulated the foramen as the mature state. For his material he reported (1930:362) bilateral notches (males 23%, females 29%), bilateral foramina (males 56%, females 53%), and asymmetrical configurations (males 20%, females 17%).

Akabori (1933) noted an average of 48.5% of males and 46.4% of females possessing foramina in modern Japanese, and concluded that the foramen was not associated with age and had no side priority. When no foramen was present Akabori always found a notch, thus supporting Oetteking's

(1930) statement that the 'pithecoid' pattern was rare. Akabori (1933:234) recorded the following frequencies; bilateral notches (males 53%, females 43%), bilateral foramina (males 23%, females 28%), and asymmetrical configurations (males 24%, females 29%).

Yamaguchi (1967) found foramina more common in females and the 'pithecoid' pattern more common in males, and Cybulski (1973) reported both notches and foramina to be bilaterally dissimilar in most cases and non-age dependent, though his study was based on a very small sample and thus its generalizations are subject to question.

Extra Ethmoidal Foramen

The suture line formed by the articulation of the ethmoid and frontal orbital plates (on the medial wall of the orbit) is interrupted by the anterior and posterior ethmoidal foramina (Gray's Anatomy 1962). These foramina are usually single and any additional one is an extra ethmoidal foramen. On occasion the posterior ethmoidal foramen may be absent (Berry and Berry 1967). In this study the presence or absence of the posterior foramen and the presence or absence of extra foramina were noted.

The two ethmoidal foramina lead into small bony canals which in turn lead into the anterior cranial fossa. Endocranially the canals open at the lateral edge of the

cibriform plate of the ethmoid bone. In life these canals transmit the anterior and posterior ethmoidal nerves and arteries, respectively, though the posterior ethmoidal nerve is often absent (Gray's Anatomy 1962). The relationship between the possible absence of the posterior ethmoidal nerve and its canal is not clear, for the posterior ethmoidal artery persists.

Both these nerves are branches of the nasociliary nerve; the posterior supplies the ethmoidal and sphenoidal air sinuses, while the anterior supplies part of the nasal mucous membrane. The anterior and posterior ethmoidal arteries are both branches of the ophthalmic artery; the former supplies the anterior and middle ethmoidal and frontal air sinuses, while the latter supplies the posterior ethmoidal air sinuses (Gray's Anatomy 1962).

Riesenfeld (1956) has stated that the frequency of multiple infraorbital foramina (see below) follows that of extra ethmoidal foramina, with American Indians, Indonesians, and Melanesians possessing the highest frequencies of both multiples, and Hungarians and African Negroes having the lowest. He therefore concludes that one factor determines the numerical variability of both. He finds the incidence of multiple infraorbital and ethmoidal foramina higher on the left side than the right.

DeVilliers (1968:126) states that although her data

do not substantiate Riesenfeld's claim that the frequencies of multiple infraorbital and ethmoidal foramina shadow one another:

...nevertheless, if one considers individual crania, it is clear that a tendency to multiple foramina in one area is often accompanied by similar tendencies in one or more other areas.

She concludes that multiplicity of parietal (see below), infraorbital (see below), and mental foramina (1968:126), "...is produced by a genetic mechanism," and that in her material on South African Negroes that mechanism is very much the same in each group studied.

Anterior Ethmoidal Foramen Position

As stated above, the anterior ethmoidal foramen is usually located on the fronto-ethmoidal orbital plate suture in the medial wall of the orbit (Gray's Anatomy 1962). It may, however, be located in the frontal or ethmoidal bones instead (Berry and Berry 1967). Presumably the control over such variation is genetic.

In this study when multiple anterior ethmoidal foramina were found (see above), the position of the largest of these was recorded.

Nasal Aperture Form

The form of the nasal aperture was classified as either pyriform, inverted-heart, or equilateral triangle. This trait has often been studied in the past (i.e. Le Double 1906) and Wood-Jones (1930-31) classified the nasal aperture as either pyriform, ovoid, oval, almost parallel sided, or circular. He states (1930-31:187) that the nasal aperture form is, "of extreme racial importance."

Nasal Profile

The profile or median curve of the nasal bones was classified as either concave, convex, straight, or concavo-convex. DeVilliers (1968) suggests that nasal profile assessment should follow Virchow's method (quoted in Martin and Saller 1957), which is to judge nasal profile in relation to a straight line joining the nasion to the rhinion. This method was used here, though DeVilliers' (1968) seven profile curves were subsumed into four broader categories.

The aetiology of variation in nasal profile has been considered by Birdsell (1949) who concluded that the growth pattern of the nasal bones was genetically independent of that of the frontal process of the maxilla, and that the relationship between these two growth patterns results in different nasal profiles. Thus nasal overgrowth (growth

tendency of the nasals exceeding that of the maxilla) results in a convex nasal profile, while nasal undergrowth results in a concave profile. In this same study Birdsell found sex differences in AmerIndian nasal profiles. Birdsell concluded (quoted by DeVilliers 1968:131) that, "... the relative growth patterns of the nasal bones (and thus their profiles) were hereditarily determined by sex-influenced factors."

Infraorbital Foramen (foramen infraorbitalis)

The infraorbital foramen is located about 1 centimeter below the orbital margin where it perforates the maxilla. It lies on, or just lateral to, a vertical line passing through the supraorbital notch, and represents the anterior end of the infraorbital canal (Gray's Anatomy 1962). The canal and foramen transmit the infraorbital nerve and artery; the nerve, a branch of the maxillary nerve, supplying the ala of the nose, the lower eyelid, and the skin and mucous membranes of the cheek and upper lip, while the artery supplies muscles Rectus inferior, Obliquus inferior, the lacrimal sac, the upper incisor and canine teeth, and the mucous membrane of the maxillary air sinus (Gray's Anatomy 1962).

There is usually one foramen per side (Oetteking 1930), but one or more extra, smaller foramina, usually above,

more rarely below or lateral to the large one, may occur (Oetteking 1930). The usual form of variation, however, is one accessory foramen on each side (DeVilliers 1968), or the dividing of a single foramen by a bony spicule. In this study single, double, and divided foramina were noted.

DeVilliers (1968) points out the necessity of distinguishing accessory foramina, wherever they may occur, from nutrient foramina. Le Double (1906) noted this problem as well. Nutrient foramina (Gray's Anatomy 1962) transmit nutrient arteries to the interior of bone, while accessory foramina transmit vessels and/or nerves through bone for extra-osseous distribution. In this study a surgical probe served to differentiate blind nutrient foramina from true accessory foramina.

Schultz (1954) found a familial incidence of multiple infraorbital foramina and suggested a genetic basis for their appearance. DeVilliers (1968:124), on the genetic basis of infraorbital foramen variation, has noted that although intragroup variability may be high, "...the frequency with which multiple infraorbital foramina occur is a racial trait."

Le Double (1906) who found no significant racial or side differences in the frequency of multiple or divided infraorbital foramina, noted 10.1% of his material with doubled foramina, and bilateral doubling less frequent than

unilateral. Oetteking (1930) noted that in general the infraorbital foramen is not necessarily bilaterally symmetrical, while Akabori (1933) disagreed with both and stated that bilateral is more frequent than unilateral doubling. Akabori found multiple foramina in 15% (both male and female) of his modern Japanese material, and noted a slight left side preference with no sex or age differences.

Riesenfeld (1956) found significant racial differences in the distribution of infraorbital foramen variants with African Negroes and Mongoloids at the extremes of frequency. He found, as did DeVilliers (1968) and Akabori (1933), the incidence of multiplicity to be slightly higher on the left side, and noted the relation between infraorbital and ethmoidal foramen variation (see above).

Zygomatico-facial Foramen

According to Gray's Anatomy (1962) the zygomatico-facial foramen is located on the zygomatic bone opposite the junction of the infraorbital and lateral margins of the orbit, and opens laterally and downwards. The zygomatico-facial nerve and artery, which the foramen transmits, follow the zygomatic arch to the cheek prominence which the nerve, a branch of the zygomatic nerve, innervates. Variations possible at this site are absence or multiplicity.

Berry and Berry (1967) seem to have introduced this trait for use in population distance studies, and include it in their computations of genetic distance without specifically discussing their rationale for doing so. Corruccini (1973) included it as well in his study and found some indication of age-association in Negro males.

Apparently, then, some genetic underpinning is assumed for the variations of the zygomatico-facial foramen.

Os Japonicum

The os japonicum, so called "since it is believed to be characteristic of the Japanese cranium" (DeVilliers 1968:137), results from the zygomatic bone being divided horizontally by a transversozygomatic suture (Yamaguchi 1967) which stretches from the middle of the zygo-maxillary suture to the middle of the zygomatico-temporal suture (Oetteking 1930). The inferior portion of the resulting bipartite zygomatic bone is termed the os japonicum.

This anomalous transversozygomatic suture is the result of two, rather than one, ossific centres which appear in membrane around the eighth intrauterine week (Gray's Anatomy 1962). DeVilliers (1968) states that whereas Frazer (1958) attributes the os japonicum to a secondary centre of ossification, Martin and Saller (1957) view its appearance as the result of secondary bone deposits.

The aetiology of this trait is apparently a "fairly simple genetic mechanism" (DeVilliers 1968:290), though Birdsell (1949) and Cybulski (1973) doubt the exact mode of inheritance would be easy to determine as the trait is affected by age. Torgersen (1951a) includes the transverso-zygomatic suture as one which irregularly occurs, and posits an aetiology in the genetic determination of ossification centres and sutures.

The earliest reported frequencies for the *os japonicum* were made on Japanese crania. Koganei (1893) reported 4.8% for Japanese and 0% for Ainu and found no sex or age difference, while Hasebe (1913) put the figure at 3% for Japanese but otherwise agreed with Koganei. Le Double (1906) found 21.1% of Japanese crania possessed this trait while French crania from Tour ranked at 0.1%. Akabori (1933) noted that the transversozygomatic suture was most often encountered bilaterally and when unilateral, showed no side preference.

Besides a full transversozygomatic suture with resulting *os japonicum*, a trace of this suture may persist as acutely angular indentations along its former path (Oetteking 1930). These traces are also usually, though not always, bilateral, and Oetteking (1930) found their incidence to be 12% in male and 17% in female crania from the North Pacific coast.

Ossenberg (1970) has defined a trace as 2-10 millimeters of anomalous transversozygomatic suture, and noted that although a full suture is rare, a trace is common especially in Asiatics and Northwest coast crania. Cybulski (1973) agrees with Ossenberg and postulates some sex and age variability.

In this study both os japonicum and transversozygomatic suture trace were noted.

Malar Tubercle

The malar tubercle, on the anterior surface of the zygoma, serves as the origin of muscles zygomaticus major and levator labii superioris (Melbye 1969). It has been shown, for instance by Anderson (1968a), that the tubercle may vary in expression from absent to well-marked.

This trait is sexually dimorphic with males showing heavier development characteristically, and Ossenberg (1970) considers it a hyperostotic variant.

Zygomaxillary Tubercle

This tubercle, a roughened downward projection at the inferior border of the zygomaxillary suture, acts as an origin for the masseter muscle (Anderson 1968a). It too, like the malar tubercle (see above) and the marginal tubercle

(see below), is considered a hyperostotic variant by Ossenberg (1970) and is sexually dimorphic.

It should be noted that in addition to, or in conjunction with, this hyperostotic factor, the heavier muscles characteristic of the male which attach to these tubercles will cause them to be more fully developed as well.

The zygomatic tubercle may, accordingly, be judged absent or well-marked, as well as intermediate.

Marginal Tubercls (processus marginalis)

A localized projection of the posterior edge of the zygoma, just below its union with the zygomatic process of the frontal bone (Anderson 1968a), this tubercle may be developed to any degree, from absent to well-marked, and shows sexually dimorphic characteristics according to Ossenberg's (1970) classification.

Oetteking (1930:94) reported the following frequencies for this trait in North Pacific coast crania:

	small	medium	large
males	19%	49%	32%
females	35%	45%	20%

It should be noted that although this and the previous two traits all seem to belong within Ossenberg's (1970) hyperostotic classification, e.g. malar, zygomatic, and

marginal tubercles, Anderson (1968a) has reported that their degree of expression is independent of one another.

Accessory Lesser Palatine Foramen (foramina palatina minora)

The lesser palatine foramina lie on both sides of the posterior border of the hard palate immediately posterior to the greater palatine foramina (Berry and Berry 1967), and piercing the pyramidal process of the palatine bone, transmit the middle and posterior palatine nerves (Gray's Anatomy 1962). These nerves supply the uvula, tonsil, and soft palate.

According to Oetteking (1930) there are usually two lesser palatine foramina on each side, and Gray's Anatomy (1962) also considers two the usual number, with one and three foramina as possible variants. Berry and Berry (1967) however, consider one per side the usual configuration and score anything over one as an accessory lesser palatine foramen. In this study one foramen was considered normal.

On the aetiology of accessory foramina in this region, DeVilliers (1968:145) concludes that control over variation is by a "fairly simple genetic mechanism."

Oetteking (1930) supplies the following frequencies for variation in number and side of lesser palatine foramina in North Pacific coast crania (1930:103):

right	left	frequency
1	1	26%
2	2	20%
3	3	3%
1	2	13%
2	1	9%
2	3	6%
3	2	4%

Pterygo-foramina

Variations in the development and relationship of the lateral and medial pterygoid processes were recommended by Wood-Jones (1930-31:194) as being worthy of study for their "racial significance." The variations of this region considered in this study include the total or partial ossification of the pterygospinous ligament, thus forming a complete or partial pterygospinous foramen of Civinini, and the total or partial ossification of the pterygoalar ligament, thus forming a complete or partial porus crotaphitico-buccinatorius of Hyrtl (pterygoalar foramen), or, as it is called herein, a pterygobasal foramen (Chouké 1946).

The pterygospinous foramen (Civinini) is formed by the total ossification of the pterygospinous ligament which stretches from the angular spine of the sphenoid to the spine of Civinini situated about the middle of the posterior

border of the lateral pterygoid lamina of the same bone (Chouké 1946; Ossenberg 1969, 1970). Usually nothing passes through the pterygospinous foramen when it is present, however occasionally (Chouké 1946, 1947) some vein or veins of the pterygoid plexus may pass through it, and more rarely, the nerve to the internal pterygoid lamina. The partial formation of this foramen, a bony spur, is also possible (Chouké 1947).

The porus crotaphitico-buccinatorius of Hyrtl, or pterygobasal foramen, is formed by the complete ossification of the pterygoalar ligament connecting the inferior surface of the great wing of the sphenoid to the lateral pterygoid plate surface near its root (Chouké 1946; Ossenberg 1969, 1970). This bar of bone is usually lateral to the foramen ovale (Ossenberg 1969) in contrast to the pterygospinous foramen which is usually below or medial to the foramen ovale (Chouké 1946). The pterygobasal foramen transmits several branches of the third (mandibular) division of the trigeminal nerve including the nerves to the muscles buccinator, lateral pterygoid, temporalis, and sometimes masseter muscles (Chouké 1946). As with the pterygospinous foramen, this structure as well may be only partially formed by a bony spur (Chouké 1947).

Wood-Jones (1930-31) feels that the ossification of these ligaments is genetically controlled and shows racial

variation in frequency. Chouké (1946) examined masticatory stress as a possible factor but concluded that if this was the causal factor, the muscle tendon, and not the ligament, would be expected to ossify. On the basis of Wood-Jones' (1930-31) statement that the usual 'pithecoid' pattern is a complete pterygospinous bar, Chouké (1946) states that these traits are most probably atavistic. DeVilliers (1968) agrees with Wood-Jones and postulates a genetic factor which controls the tendency for abnormal ossification of ligaments.

The frequencies for variations in the pterygoid region are well reported though Chouké (1946) notes that not all observations are valid due to differences in definitions of the variants. Le Double (1906) reported frequencies of 4.5% for pterygospinous and 1.2% for pterygobasal foramina in Europeans, while Oetteking (1930) found 5.9% of North Pacific coast crania possessing the pterygospinous foramen.

Akabori (1933) reported that 3% of the male and 1% of the female modern Japanese have pterygospinous foramina, and suggested this trait was age-independent. He recorded 0.5% of the males and 1% of the females as possessors of pterygobasal foramina, and for this variation he noted a right-side priority.

Chouké (1946:206, 1947:80-81) recorded the following frequencies for Negro and white crania in the Terry and Todd Collections:

pterygospinous complete

	white	Negro
male	9.6%	2.8%
female	6.7%	1.4%

pterygobasal complete

	white	Negro
male	5.2%	13.6%
female	3.1%	8.1%

He noted (1946, 1947) their bilateral occurrence in 5.7% of the crania, and found neither sex, age, or side to be significantly correlated with the traits.

In 1947 Chouké extended his researches to incomplete pterygospinous and pterygobasal foramina, in the form of spurs, and recorded the following for the Todd Collection crania (1947:82-84):

pterygospinous spur

	white	Negro
male	37%	13.5%
female	37.7%	14.7%

pterygobasal spur		
	white	Negro
male	11.6%	29.2%
female	4.5%	25%

He concluded that for both complete and spur pterygospinous and pterygobasal foramina racial differences between white and Negroes were significant.

Ossenberg (1970) found the pterygospinous foramen to be fairly common and age-stable in New World crania, while pterygobasal foramina were very rare and age-progressive. She found no group or individual correlation between these two traits in New World crania, while DeVilliers (1968) does report significant correlation between the ossification of both pterygospinous and pterygoalar ligaments.

Vesalian Foramen (sphenoidal emissary foramen)

When present the Vesalian foramen is located 2-3 millimeters to the anteromedial aspect of the foramen ovale (Wood-Jones 1930-31; Ossenberg 1970). Wood-Jones notes that it may appear as a single foramen, as many orifices, or as a slit, and that it may be regular and rounded, or irregular in both size and shape. He also regards the anterior chamber of a foramen ovale divided by a bony spicule as a Vesalian foramen. In this study the Vesalian foramen was considered, by definition, to be physically independent of ovale and to

its anteromedial aspect after Ossenberg (1970).

Wood-Jones (1930-31) considers three aetiologies for the Vesalian foramen. The first, division of the foramen ovale into anterior and posterior chambers, has been discussed and, as noted, the anterior chamber of such a division was not considered a Vesalian foramen as Wood-Jones advocates. The second is a replacement of the foramen ovale as the main venous channel by a Vesalian foramen, in which case the Vesalian foramen rather than the ovale then transmits the mandibular nerve and accessory meningeal artery (Gray's Anatomy 1962). Such a Vesalian foramen would be situated anteromedial to a small foramen ovale. The third aetiology mentioned by Wood-Jones (1930-31) is the addition of a Vesalian foramen as a medial venous foramen, acting functionally as an accessory foramen ovale.

Wood-Jones (1930-31:189) views the Vesalian foramen as "an expression of the differentiation of cranial venous outlets characteristic of Homo," and notes that it only occurs in man. He states that the Vesalian foramen may appear unilaterally or bilaterally, and that the foramen ovale is smaller on the side(s) on which a Vesalian foramen appears.

Ossenberg (1970) states that there is no sex priority or pair correlation but that it is more common on the left when unilateral. In addition she found an age correlation, to wit, a decrease in incidence from childhood to adolescence

and a subsequent increase in frequency.

Foramina Ovale and Spinosum

The foramina ovale and spinosum are usually patent, the former transmitting the mandibular nerve and accessory meningeal artery, and the latter the meningeal branch of the mandibular nerve and middle meningeal artery. Ovale pierces the greater wing of the sphenoid posterior to the foramen rotundum, and spinosum lies close to the posterolateral margin of ovale (Gray's Anatomy 1962).

Occasionally this posterolateral wall of the foramen ovale is incomplete, and the two foramina become continuous (Berry and Berry 1967). Several other variations are possible here (see Wood-Jones 1930-31), however this variation alone was considered in this study.

Presumably the ossification of the bony isthmus which normally separates foramina ovale and spinosum is under genetic control.

Ossenberg (1970) reports that all variations in the relationship of foramina ovale and spinosum are slightly age-regressive in juveniles and stable in adults.

Anterior Condylar Canal (canalis nervi hypoglossi)

The anterior condylar canal, or canalis nervi hypoglossi, is located above the anterior part of the occipital condyle

and there pierces the occipital bone and runs laterally and slightly forwards from the posterior cranial fossa (Gray's Anatomy 1962; Berry and Berry 1967). The canal transmits the hypoglossal nerve (the motor nerve of the tongue), a meningeal branch of the ascending pharyngeal artery, and a small emissary vein from the basilar plexus (Gray's Anatomy 1962).

The canal is bilateral and usually consists of two equal-sized holes (Oetteking 1930), but may be subdivided, entirely or partially, by a bar of bone. In the case of partial division this is a spicule of bone.

Both Gray's Anatomy (1962) and Berry and Berry (1967) agree that this variation may be due to the composite origin of the hypoglossal nerve which embryologically ramifies, in several segments, from the vagus and cervical nerves. Oetteking (1930) agrees that the variation is rooted in ontogenetic conditions, but suggests the doubled canal is a manifestation of anomalous occipital vertebrae.

Lillie (1917) suggested the double canal is more frequent on the left side, while Oetteking's (1930) coast data showed double left canals in 11.8% of the crania, and double right canals in 13%. He found 11% of the crania with single right and divided left canals, however.

Akabori (1933) found double canals non-age-dependent with males showing greater frequency than females (22% versus

14%). In addition he states that the variant is usually unilateral with a right-side preference. Ossenberg (1970) disagrees and finds the trait increases a bit with age.

Posterior Condylar Canal (*canalis condyloideus* or *foramen condyloideum*)

The posterior condylar canal, when present, pierces the condylar fossa which is a depression of variable depth lying behind the occipital condyle (Gray's Anatomy 1962). When present its inner orifice lies behind and lateral to the orifice of the hypoglossal canal (see above), and it transmits an emissary vein which connects the sigmoid sinus to the cervical plexus (Oetteking 1930; Gray's Anatomy 1962). Berry and Berry (1967) have noted that it may end blindly in the bone and have scored it as present only when a probe showed it to be patent. Such a procedure was employed in this study as well.

Oetteking (1930) postulated a compensatory correlation between small jugular foramina and the presence of a posterior condylar canal but was unable to show such a correlation empirically.

Hrdlicka noted the canal "as of interest only because of more or less frequent absence from one or both sides in different racial groups" (1904:14). Wood-Jones (1930-31:195) called it a "distinctive human possession" and noted its

wide variation among different racial types. He says, as well, that the condylar fossa, its size and shape, and the posterior condylar canal, its absence or presence, are totally independent of one another.

Oetteking (1930) recorded a right canal only in 5%, a left canal only in 8%, and no canal in 5% of crania examined from the North Pacific coast, and agreed with Wood-Jones (1930-31) that this trait is usually absent in anthropoids. Boyd (1930) found it bilaterally in 47%, right alone in 17%, left alone in 14%, and absent in 23% of crania examined, while Akabori (1933) found it usually bilateral with no age or sex dependence (males 89% versus females 90%). Ossenberg (1970), on the contrary, found a preference for females and the right side, and claimed a decrease in frequency from childhood to adolescence with increasing frequency thereafter.

Occipital Condyle Form

The shape of the articular surface of the occipital condyle is variable and usually bilaterally symmetrical. This study considered three variations: single or oval, hour-glass, and complete division of the articular surface into two distinct condyles. These variations have been recorded by Berry and Berry (1967), Anderson (1968a), and Halprin (1973).

Precondylar Tubercls (tuberculum precondyloideum or labia
foraminis magni anteriora)

According to Le Double (1903) the precondylar tubercle(s) is located a few millimeters in front of the anterior border of the foramen magnum or on that border itself, and is most often on both sides of a median line separated, more or less, from each other. They are (1903) osseous growths of variable size and form, may be bilaterally symmetrical, and may be continuous with the occipital condyles. Berry and Berry (1967) state that when the tubercle is on the median line it represents two fused tubercles.

The variations in size and shape of this tubercle are many as Broman (1957) has noted. Yamaguchi (1967) has observed a bony process at the median point of the anterior margin of the foramen magnum projecting towards the posterior margin and has called it the third occipital condyle stating that it does articulate with the atlas (first cervical vertebra).

In this study any bony protuberance situated medially on the anterior margin of the foramen magnum was noted including the full articular facet described as possible by Yamaguchi.

Broman (1957) has reviewed the literature on this trait and has shown three theories regarding the aetiology of the variation: 1. formation of a precondylar tubercle occurs during ossification of the occipital bone as an ossification

variation; 2. a tubercle forms due to the partial or complete ossification of the atlanto-occipital and/or the anterior longitudinal ligament, and 3. the tubercle forms as a result of artificial cranial deformation. Broman postulates a combination of the first two theories as a probable aetiology.

Assuming that the tubercle is in fact the result of occipital and ligamentous ossifications, De Villiers (1968) has posited a genetic control for the abnormal ossification of ligaments, and Torgersen (1951a) has shown genetic control over cranial bone and suture formation. It may be tentatively concluded then that the variation of precondylar tubercles is at least partially under genetic control.

Oetteking (1930) reported labia foraminis magni anteriora present in 15% of his material, while Akabori (1933) cites Legge's figure of 0.3% occurrence in European crania. Akabori's own modern Japanese data shows the trait to be independent of age or sex (6% males versus 4% females), and usually symmetric with no side preference in those crania found with unilateral occurrence. He reports the presence of medial tubercles in 10% of his sample.

Marshall (1955) has published incidence rates for precondylar tubercles and the reader is referred to his work.

Ossified Apical Ligament

The apical ligament of the dens extends from the tip

of that process to the interior margin of the foramen magnum on its anterior side (Gray's Anatomy 1962). At the point of its attachment to the foramen magnum it may ossify, usually as a small bony point, but occasionally of sufficient size to be termed a tubercle (Melbye 1969).

This trait, like others involving the ossification of a usually non-ossified structure (Anderson 1968b) appears to involve an inherited tendency for abnormal ossification (DeVilliers 1968).

Paramastoid (processus paracondyloideus)

The paramastoid represents different developmental stages of the inner lip of the digastric fossa or incisura mastoidea (Oetteking 1930). Gray's Anatomy (1962) defines it as a downward projecting process from the under-surface of the jugular process of the occipital bone which may, if projecting enough, articulate with the transverse process of the atlas (first cervical vertebra) via its own articular facet.

DeVilliers (1968:119) attributes this trait to a "fairly simple genetic basis."

Oetteking (1930) reports the process present bilaterally in 25% of his material, with unilateral occurrences less than 1% per side. DeVilliers (1968), summarizing her own work and others', notes its occurrence in both sexes of all

populations, though it is extremely rare in Negro, Caucasoid, and AmerIndian groups. Gaherty (personal communication) reports however, that while rare in South African crania, the process is present in 18-52% of African crania examined.

Sagittal Sinus Direction

The superior sagittal sinus runs endocranially from the glabella to the inion along the median endocranial line. Along its course it receives venous drainage from the peri-cranium (Gray's Anatomy 1962). At the confluences of the sinuses, near the internal occipital protuberance, it deviates to one side or the other (usually right) and continues on as the corresponding transverse venous sinus. It may, occasionally, split into equal halves, both right and left.

It is presumed that control over the sagittal sinus direction is genetic and heritable.

Laughlin and Jørgensen (1956) first used this variant in their study of the Greenlandic Eskimo. Anderson (1963) studied the bilateral condition, known as the confluens sinuum, and Cybulski (1973) found a right deviation favoured over a left, 71% versus 29%.

Parietal Foramen (foramina parietalia)

The parietal foramen pierces the parietal bone near the sagittal suture and about 3.5 centimeters in front of

the lambda (Gray's Anatomy 1962; Berry and Berry 1967). It transmits an emissary vein from the superior sagittal sinus (though O'Rahilly and Twohig doubt it [1952]) and sometimes a small branch of the occipital artery. This emissary vein constitutes one of the most important communications between the extra- and intracranial veins (Gray's Anatomy 1962) and as such is a prime avenue for the spreading of scalp and/or cranial infection to the brain.

One parietal foramen is usually present on each side of the sagittal suture (Oetteking 1930) but its absence or multiplicity may occur on either side. In addition foramina parietale impar (Oetteking 1930) may occur in which the foramen is situated in the sagittal suture. In this study all variations except the foramina parietale impar were considered.

Regarding the aetiology of this trait and its variations, Hess (1946) stated that parietal foramina and ossicles (see below) were manifestations of the same phenomenon, while Padget (1956) and Hertzog (1968) felt that the foramina represent the imperfect closure of the sagittal fontanelle. DeVilliers (1968) holds that some heritable genetic mechanism controls the variation of this trait.

Oetteking (1930) records the single, bilateral occurrence of the foramen in 55% of his material and notes that in the absence of the foramen small pores are often found. He finds that when the trait is unilateral the right side is

favoured, a conclusion with which Akabori (1933) and Ossenberg (1970) agree. Akabori noted as well that the right foramen tends to be larger than the left.

Based on the following data Akabori (1933:204) concluded that the foramina were usually singly bilateral, and rarely impar:

right	impar	left	f
1	0	1	52%
0	0	0	18%
1	0	0	16%
0	0	1	10%
0	1	0	3%

He found no age or sex difference. Akabori (1933) cites Augier's data on the French as 70% present (bilateral, single), and Bartel's on orangutans and hylobates as 38% and 15% present, respectively. Akabori concludes, therefore, that absence of parietal foramina is a 'primitive' condition.

Hertzog (1968) found no significant correlation between these foramina and 6 other cranial traits, while Ossenberg (1970) found a small age-progressive trend and female priority.

Coronal Wormians (os coronarium)

Pucciarelli (1974) defined wormian bones in general as all supernumerary intra- and intersutural bones limited on

all sides by sutures. Such ossicles may occur in the coronal suture, especially in the pars complicata (Ossenberg 1970), and may vary in number.

The aetiology of coronal wormians has long been discussed and it should be noted that the following review will be referred to when discussing the aetiology of other wormian bones.

Dorsey (1897) found coronal wormian bones in artificially deformed Kwakiutl crania to be due to bandaging in early life and the frequency of the ossicles increased with the degree of anterior-posterior deformation and in direct proportion to the development of a deep, well-defined groove behind the coronal suture which was caused by the downward pressure of the bandages. Dorsey concluded that the elongation and groove prevent normal frontoparietal development with resulting ossicles as 'stop-gaps'. Sullivan (1922) found coronal wormians very rare in American crania and found artificial deformation correlated only with lambdoid wormians (see below).

Oetteking (1930) found coronal wormians in about 7% of North Pacific coast crania examined. He noted, as did Sullivan (1922), that though they may originate without mechanical stress yet they increased in frequency when deformed skulls were involved so that some deformatory influence, at least in the coronal suture, was involved. Oetteking (1930)

noted further that coronal wormians were rare and occurred mostly in the pars complicata, and concluded that coronal ossicles in undefomed skulls occurred often in conjunction with bregmatic bones, and stated that in general wormian bones in the undefomed skull were due to evolutionary processes which could be mechanically intensified, and further that both fontanelle and wormian bones were derived from independent ossific centres and in completed state were separated by sutures from adjoining bone.

Pucciarelli (1974) cites Dinwall (1931) as finding no influence on wormian bones by artificial cranial deformation, while Wood-Jones (1930-31) stated that the trait belongs to a group of non-adaptive discontinuous features which could be useful in racial differentiation. Akabori (1933), finding coronal wormians in 2% and 1% of males and females respectively, concluded that the trait was non-age dependent, usually not bilateral, and had no side or sex priority.

Hess (1946) considered wormians to be caused by hypostosis, a bone deficiency caused by an inherited metabolic disorder of the mesoderm, while Torgersen (1954) concluded that sutural variations were inherited as a dominant trait with 50% penetrance and variable expression dependent upon genes for general head shape.

Both Moss (1954) and Young (1959) produced wormian bones experimentally in rats, and Storey (1955), working with

rabbits, found that growth of bone at sutures may be initiated by tension, that the growth of serrated sutures in the skull results from tensile stress exerted between adjoining bones, and that when this stress is great wormian bones may be formed in the sutural connective tissue.

Bennett (1965) agreed with Storey's findings stating that secondary sutural characteristics were developed in response to localized stress caused by growth-rate differences in two adjoining bones.

Ossenberg (1970) found that deformation disturbs the inherited pattern of wormian bone distribution, and that wormians in general are age-progressive with sex and side differences varying from population to population.

Thus it would seem that while wormian bones are a phenotypic manifestation of a genotypic condition, their expression may be effected by mechanical stress.

Bregmatic Bone (interfrontal bone)

A wormian bone may occur at the bregma, the intersection of sagittal and coronal sutures (Berry and Berry 1967), which fills in the primary osseous gap of the anterior (or frontal) fontanelle (Oetteking 1930). It usually progresses posteriorly, and when it extends anteriorly is in conjunction with a metopic suture (Oetteking 1930), though Brothwell (1963) considers this an interfrontal, as distinguished from

a bregmatic, bone.

The reader is referred to the section on coronal wormian bones for a discussion of aetiology.

Sullivan (1922) found bregmatic bones to be very rare, and cites Russel's (1900) study of its incidence, while Comas (1942) reported that its incidence was 1.4% in skulls with metopic sutures and 0.39% in those without. Le Double (1903) reported an incidence of 0.6% in Europeans and 0% in non-Europeans except ancient Peruvians (2.3%), while Akabori (1933) found none in 413 modern Japanese crania.

Hertzog's (1968) work on the possible regional correlation of cranial traits (though see Benfer 1970) led him to believe that the contents of the anterior cranial fossa could produce variation in the anterior neurocranial vault, and that frontal brain size affects the frontal fontanelle in which an increase in size increases the likelihood of finding ossicles. Hertzog (1968) cites the literature to show a sexual priority for this trait.

Sagittal Wormian Bones

These ossicles within the sagittal suture are reported by Oetteking (1930) in 1% of crania examined. Brothwell (1963) too, finds them rare, while DeVilliers (1968) states they are usually small and paired.

The reader is referred to the section on coronal

wormian bones for a discussion of aetiology.

Lambdoid Wormian Bones

A variable number of ossicles may occur within the lambdoid suture not including the lambda (posterior fontanelle) or the asterion, which may produce lambdic and asterionic bones respectively (see below). Berry and Berry (1967) have noted as many as 12 ossicles in the lambdoid suture.

The aetiology of lambdoid wormian bones seems to be genetic but not directly so (Bennett and Hulse 1966). Bennett (1965) has stated that the variable types and amounts of stress applied to the posterior parietal margin during foetal and early post-partum life by the variable development and growth of the basi-occiput are responsible for the variations, including ossicles, seen in that region. Thus Bennett (1965), Bennett and Hulse (1966), and DeVilliers (1968) view lambdoid ossicles as being a trait genetically controlled through the variable growth and development of the basi-occiput.

Martin (1914) noted ossicles in 3.5% of Bavarian and 1.4% of Old Bavarian crania, and Sullivan (1922) found the majority of lambdoid ossicles to be in the area of, though not in, the lambda. Oetteking (1930) found lambdoid ossicles in 25% of North Pacific coast crania studied, the highest percentage incidence of any intrasutural bone, and Anderson (1968a) too, notes the lambdoid to be the most common ossicle-

containing suture.

Akabori (1933) found this trait not to be dependent upon age or sex and recorded bilateral occurrences in 26% of his sample. Of unilateral occurrences, Akabori found the right side favoured.

Lambdic Bone

A lambdic bone, as differentiated from a lambdoid ossicle, is one which is situated on the lambda rather than in the lambdoid suture (see above). Several variations are possible at the lambda (e.g. os apicis, os triquetrum) but only two have been considered in this study; a lambdic bone (ossicle at lambda), and the inca bone.

The os incae represents the anomalous ossification of the upper squamous (membranous) part of the occipital bone so that a suture occipitalis transversa, running from asterion to asterion, separates this upper portion from the rest of the occipital (Anderson 1963; Sullivan 1922; Oetteking 1930; Akabori 1933). It is thus a true inca or interparietal bone only when it is large and includes that portion of the occipital bone above the inion (Sullivan 1922).

Bennett and Hulse (1966) state that Hepburn's (1908) claim for a genetic basis for the os incae is fully substantiated, while Torgersen (1951a) holds that the os incae and metopic suture (see above) are at least partially mani-

festations of the same genetic phenomenon.

Sullivan (1922) cites Matthew's (1893) statistics for the presence of the inca bone as 1.2% in Caucasians in general, 1.7% for Caucasians in Asia, and 1.1% for Europeans, while Martin (1914) reported 1.2% for Europeans, 0.5% for Bavarians, 2.3% for Mongols, 2.6% for Negroes, and 4.8% for North Americans. Koganei (1893) reported 0% incidence among the Ainu, and Hori (1925) gave 1.5% as the frequency in Japanese. Akabori (1933) reported no age correlation for the inca bone and a 1% incidence in the modern Japanese crania he studied.

Sullivan (1922) found a correlation (r_2) of .53 between the inca bone and metopic suture, and .20 between tympanic dehiscence and the bone. Oetteking (1930) gives a range of 5.1-23.4% incidence in ancient Peruvians among whom this trait was first observed, and among North Pacific coast crania he reports .75% and .25% for males and females respectively.

Brothwell (1963) has pointed out that the inca bone and lambdoid ossicle are of different aetiologies. In this study a lambdoid ossicle was considered to be any intersutural bone at the lambda which did not fit the definition of an inca bone. The reader is referred to the section on lambdoid ossicles for a discussion of their aetiology.

Pterion Shape

The pterion is that region on the lateral exocranial vault where the frontal, parietal, sphenoid, and temporal bones approximate one another, and it is the nature of their approximation that constitutes the variation seen at the pterion.

There are basically five types of pterionic articulation: 'H' form in which only the parietal and sphenoid bones are in contact (Sullivan 1922), 'X' form, or stellate, in which all four bones meet at one point (Sullivan 1922), 'K' form in which temporal and frontal bones contact (DeVilliers 1968), 'I' form in which fronto-temporal articulation takes place via a thin suture line (DeVilliers 1968), and epipteric, or pterionic ossicle, in which an ossicle is inserted between the four bones (Oetteking 1930). In this study forms 'H', 'X', 'K', and epipteric bone were differentiated.

Murphy (1956) has ascribed the various forms of the pterion to mechanical factors and the genetics determining the rate of growth of the four bones involved, and Torgersen (1954) has stated that a pterionic ossicle is genetically controlled.

Bauer (1915) recorded that the normal arrangement for some anthropoids and Old World monkeys is fronto-temporal, and summarizing previous workers, stated that in 11,000 Europeans the fronto-temporal pterion occurred in 1.53%,

while Sullivan (1922), noting that in a given group the pterion form is fairly uniform, stated that in crania of indigenous AmerIndians 75-95% were of the 'H' type, and the 'X' type was least common. He stated as well that an epipteris ossicle occurs most often in groups with high frequencies of fronto-temporal articulation. Ashley-Montagu (1933) noted as well a high positive correlation between pterionic ossicles and the "pithecoid" (Wood-Jones 1930-31:186) pattern of fronto-temporal articulation with many cases of the latter resulting from union of an epipteris ossicle with the temporal bone.

Collins (1930) noted no sex priority in pterion form, but Oetteking (1930) did. He reported the os epipteris to be unilateral more often than bilateral, and more common in males (9%) than females (7%). Oetteking (1930), moreover, studied only 'true' epipteris bones, e.g. those possessing suturae epipterico-frontalis, epipterico-parietalis, epipterico-squamosa, and epipterico-sphenoidal. He felt that such ossicles could be traced to either a fontanelle bone destined to fill the membranous interval of the infant skull at the junction of the four bones, or an accessory membranous element in man appearing above the cartilagenous wing of the sphenoid.

Akabori (1933) differentiated between six types of os epipteris: proprium, anterius, posterius, medium,

inferius, and anteroinferius. Of these six, of which only proprium type satisfies Oetteking's (1930) requirements, Akabori noted no age priority but did find a left side preference. Combining the frequencies of all six types, Akabori found in modern Japanese a 30% incidence in males and a 41% incidence in females, and for the os epiptericum proprium alone he found incidences of 15% and 20% respectively. He concluded, therefore, that a female priority did exist.

On the frequency of other pterionic variations, Akabori (1933) found forms to be bilaterally symmetrical (2.5% asymmetrical), and found fronto-temporal articulation to be non age-dependent but distinctly sex dependent (males 0.5% versus females 2%) thereby contradicting Collins' (1930) statement. Akabori found the 'X' form non age-dependent but sexually dimorphic (0.5% males versus 1.2% females).

Comas (1942) found the 'K' and 'X' forms more frequently in metopic skulls than the 'H' form, and noted epipteritic ossicles in 21.1% of metopics versus 11.6% of non-metopics. He too found the ossicles to be more frequent in females.

Akabori's (1933) division of the os epiptericum into six forms has since been modified. Berry and Berry (1967) consider a pterionic ossicle to be any between the anterior inferior angle of the parietal bone and the greater wing of the sphenoid, noting that large ones may articulate with the

squamous part of the temporal bone. Ossenberg (1970) considers an epipubic bone to be one that articulates with two or more sutures at the pterion, and this definition was used in this study to judge the presence or absence of this variant.

Parietal Notch (incisura parietalis)

In that part of the parietal bone that extends between the squamous and temporal portions of the temporal bone (Berry and Berry 1967) a notch (incisura parietalis) or ossicle (os incisura parietalis) may appear.

Brothwell (1963) states that nothing is known of the aetiology of either of these variants, while Herzog (1968) alludes to factors that are neither site-specific nor general, but that may affect the posterior and not the anterior of the cranial vault. This does little to disprove Brothwell's statement.

Oetteking (1930) says that the parietal notch bone is generally absent in the lower apes but present in the orangutan. He finds it in man less often than an asterionic bone (see below) and notes that the parietal notch bone is best explained as a sutural bone since it does not occur at the site of a fontanelle. He found it present in 85% and bilaterally dissimilar in 15% of the North Pacific coast crania he examined.

Laughlin and Jørgensen (1956) state that a notch bone, occurring at the lower extremity of the notch, was observed by Weidenreich (1943) in his study of Sinanthropus pekinensis, and they used it to help distinguish Greenlandic Eskimo populations.

Akabori (1933) recorded that while the notch bone was usually unilateral with no side preference, age or sex priority, the notch itself showed marked sex differences in development.

Asterionic Bone

At the asterion, the junction of the posterior inferior angle of the parietal bone with the occipital bone and the pars mastoid of the temporal bone, an ossicle may be present (Berry and Berry 1967). This is the site of the former mastoid fontanelle.

The reader is referred to the section on coronal wormian bones for a discussion of aetiology.

Oetteking (1930) noted that the asterionic bone was more frequent than parietal notch bone. Akabori (1933) states that a true asterionic bone must articulate with the occipital, parietal, and temporal bones, and he notes no age or sex differences but finds it predominantly unilateral with a right side priority.

Mastoid Foramen (foramen mastoideum)

The usual location of the mastoid foramen is in the occipito-mastoid suture. This foramen transmits a meningeal branch of the occipital artery and an emissary vein from the sigmoid sinus. Akabori (1933) states that the usual configuration is one foramen per side, and Oetteking (1930) has noted that variations in the forms of multiplicity and absence are not rare.

Regarding aetiology, DeVilliers (1968) has suggested that the genetic mechanism Riesenfeld (1956) claims for multiple ethmoidal, infraorbital, and mental foramina is a mechanism affecting the skull in general, much in the same way as Hertzog's (1968) regional genetic control of cranial morphology, and that this genetic mechanism, or one very much like it, accounts for variations in the number of mastoid foramina as well.

Boyd (1930) reported no age or sex priorities in the number of mastoid foramina, while Oetteking (1930) showed their bilateral absence in 10% of crania for both sexes, and their asymmetrical presence in 35% of crania for both sexes.

Akabori (1933) recorded total absence in 13% of male and 20% of females crania examined, and single, bilateral foramina in 87% and 80% respectively. He found multiple foramina to occur with slightly higher frequency in females

with no side priority, and noted that rarely is the foramen missing unilaterally. An age priority was found in that the single, bilateral configuration occurred slightly less frequently in younger crania, especially among the females, and after the 20-30 year level the frequencies stabilize.

Mastoid Foramen Position

The most usual position for the mastoid foramen is in the occipitomastoid suture, between the pars mastoid of the temporal bone and the occipital bone (Oetteking 1930; Berry and Berry 1967). It may also be located in the pars mastoid of the temporal bone, or, more rarely, in the occipital bone (Berry and Berry 1967). Its location is presumably under some kind of genetic control.

Akabori (1933:102) recorded the following incidences of this variation in modern Japanese crania:

	males	females
temporal	57%	72%
suture	27%	21%
occipital	17%	7%

In this study, in the case of multiple foramina (see above), the position of the largest was determined.

Divided Mastoid (sutura mastoideosquamosa)

The mastoid process is a result of the embryological

fusion of the squamous and petrous parts of the temporal bone (Oetteking 1930), and the resulting suture, while usually obliterated by the end of the second year of life, may persist in full or in trace.

The aetiology of this variation is not known though Torgersen (1951a) has said that the underpinnings of suture obliteration are surely genetic.

Sullivan (1922) reported that full persistence is very rare, though traces are very frequent in Eskimo crania. Oetteking (1930), agreeing with Sullivan's statement, noted that caution must be exercised in observing traces of the mastoid suture for it may be blurred by tuberosities for the insertion of muscles sternocleidomastoid and splenius, but that in such cases the suture trace may be observed above the tuberosities. Oetteking also observed deep gaps or pits in the suture line but noted that these did not connect with the mastoid cellulae.

Akabori (1933) made the interesting observation that retention of the mastoid suture, or its trace into adulthood was almost independent of age, against the law of suture obliteration as is metopism. He noted little sex difference for the presence of the suture or its trace (40% of males versus 38% of females), no side priority, and found, on the average for combined sexes 60% absence, 28.6% trace, and 4.6% complete retention.

In this study the absence, trace, or full retention of the suture were noted.

Tympanic Dehiscience

The floor of the external auditory meatus is formed by the tympanic plate. This plate, or its anteriorly directed wall (Oetteking 1930), may show a dehiscence or perforation, which is known as the foramen of Huschke.

The aetiology of this fault has been much speculated about. Sullivan (1922) saw it as a maldevelopment due to retarded growth. Oetteking (1930) stated that in adolescents it was due to incomplete ossification of partas tympanica and petrosa which usually fuse about the fifth year, whereas in adults it was due to the action of the mandibular joint in conjunction with atrophy of the plate.

Anderson (1962b) has explained that a dehiscence results when the distal portions of the developing tympanic plate meet and fuse while the proximal parts fail to do so. This fusion occurs normally by the fifth year, and if it fails, a foramen of Huschke will result in the medial third of the plate. The cause of this failure of fusion (Anderson 1962b:152) "is presumably due to a genetically determined error in ossification."

Wood-Jones (1930-31) recognized the high variability of this trait between populations and Oetteking (1930)

found it common in American crania, usually bilaterally, and most frequent in females. Sullivan (1922), citing Hrdlicka (1906), reports incidences of 28% and 46% in males and females from California, respectively. Sullivan reports the trait is usually bilateral, and shows no significant correlation with inca bones, metopic sutures, or lambdoid wormian bones.

Akabori (1933) recorded no age or side priority, but, as did Sullivan (1922), Oetteking (1930), and Anderson (1962b), he reported a distinct sex priority for females. Anderson (1962b) noted that when unilateral the left side shows preference, and Ossenberg (1970) showed a sharp decrease in 8-12 year olds and a stabilization of frequency afterwards.

Tympanic dehiscence was noted as absent or present in this study.

Tympanic Thickening (os tympanicum hyperostosis)

The tympanic plate, forming the floor of the porus acusticus externus, may be thickened to varying degrees (Oetteking 1930). Wood-Jones (1930-31) says that on unthickened tympanic plate produces a smooth, thin edge at the external extremity of the acoustic canal, whereas the thickened tympanic forms a rough, thick edge for the attachment of the perivascular fascial sheaths.

Oetteking (1930) states that this trait is characteristic of 'primitive' man, including Eskimo and Homo sapiens

neanderthalensis. He found it present in 98% of North Pacific coast crania examined and concluded that as it is seen in adolescents, and so develops before the annulus tympanics has assumed its final shape, mechanical factors, such as the wearing of heavy ear ornaments, are negligible in its aetiology.

Wood-Jones (1930-31) noted its extreme racial variability and claimed that the typical 'pithecoid' pattern is smooth and unthickened. Only the gorilla, he noted, ever possesses the thickened tympanic plate seen in man.

Stewart (1933) found distinct racial variation in tympanic plate form and concluded that though possibly influenced by diet or disease affecting ossification, the form of the plate is a hereditary characteristic.

DeVilliers (1968) found this trait to be sexually dimorphic but not at the 0.01 level of probability.

The absence or presence of tympanic thickening was noted in this study.

CHAPTER 4

METHODS OF ANALYSIS

(I) Data Collection

This study of non-metrical, morphological cranial traits utilizes a data collection and codification system established by the Physical Anthropology Laboratory, Skeletal Biology Division, at the University of Toronto. In its entirety this system supplies the investigator with a format for observing and recording data on human skeletal biology, including metrical and non-metrical traits, and pathology. The system covers the entire human skeleton. Within this system are 46 non-metrical cranial traits (of which 40 are used here) and a method for recording the various states of expression of those traits using numbers and letters. The system allows for the recording of discontinuous traits (those which are either present or absent), as well as continuous ones (those whose presence may vary by degree).

The University of Toronto data recording system uses a 76 column recording sheet with one trait per column. The additional 30 blanks are used for material identification and additional observations that the investigator might

wish to add. Data so recorded are directly transferable to standard 80 column computer punch cards, thus enabling electronic computer analysis (see Part II).

In this section the columns of the recording blank, and the codes used to record each trait are described. It will be noted that in some cases the University of Toronto system supplies codes which were not used. This is because the material under examination did not evidence this expression for a particular trait.

As previously noted, the University of Toronto system covers the entire human skeleton. Only two data cards (C and D) of the system were used in this study. Columns 1-10 of these two cards are for material identification and are identical. They will be described first. The following is a description of each column for which a value for each specimen was recorded wherever the material allowed it.

Column 1: Card Data Identification

C = Cranial Morphology (cont.)

D = Cranial Morphology (conclu.)

Column 2: Sex

0 = indeterminate

1 = male

2 = female

Standard anthroposcopic characters, as outlined by Krogman (1962), McKern and Stewart (1957), and Bass (1971), were used to determine the sex of crania.

Column 3: Age

- 0 = indeterminate, child
- 1 = under 2 years
- 2 = 2-6 years
- 3 = 6-12 years
- 4 = 12-18 years
- 5 = young adult (18-35 years)
- 6 = middle-aged adult (35-55 years)
- 7 = old adult (over 55 years)
- 8 = indeterminate, adult
- 9 = unknown or indeterminate

Only mature crania were used in this study, and a mature specimen was considered to be one in which the spheno-occipital suture was observed to be at least half fused exocranially. Krogman (1962) states that this suture fuses by 18-21 years in both sexes. Therefore, only codes 5, 6, 7, or 8 were used in recording cranial age. Determination of age, within the 'over 18' limitation, was achieved by observing the state of exocranial suture closure. Again, Krogman (1962) was used as the source for timing of exocranial suture closure.

Columns 4 - 7: Group Number

The group number is designed to be "roughly equivalent of a component of a site" (University of Toronto Codification Form). In the case of this non-archaeological study, the assignation consists of a four letter contraction for each population, to wit:

FRNC = Frank

GAUL = Gaul

BRGN = Burgundian

MRVG = Merovingian

CRLG = Carolingian

BASQ = Basque

Columns 9 - 10: Burial

In this study these spaces are used to designate individual skulls using the last three digits of the Musée de l'Homme, Laboratoire d'Anthropologie accession number.

CARD C

Column 11: Metopic Suture (MET. SUT.)

0 = absent

1 = trace

2 = half

3 = complete

Columns 12 and 13: Right Frontal Grooves (R. FR. GR.)

Left Frontal Grooves (L. FR. GR.)

9 = present

0 = absent

Column 14: Brow Shape (BRW. SHP.)

0 = absent

1 = discontinuous

2 = straight

3 = V-shaped

Column 15: Brow Rugosity (BRW. RUG.)

0 = absent

1 = +

2 = ++

3 = +++

4 = ++++

In scoring all continuous traits, as above, a system of 'pluses' is used, to wit: + = trace, felt but not seen, ++ = slight, +++ = moderate, and ++++ = marked. The marked condition represents the maximum expression seen in the series of crania examined. This system of scoring is obviously highly subjective and for this reason not wholly acceptable. To counteract this subjectivity it would be preferable to reduce such traits to a bimodal state of present/absent. However, such a reduction is not possible

when attempting to maximize cell-size for chi-squared analysis (see Part III).

Columns 16 and 17: Right Supraorbital (R. SU. OR.)

Left Supraorbital (L. SU. OR.)

0 = absent

1 = 1 foramen present

2 = 2 foramina present

3 = 1 notch present

4 = 2 notches present

5 = 1 foramen and 1 notch present

6 = 1 foramen and 2 notches present

7 = 2 foramina and 1 notch present

9 = 3 foramina present

Columns 18 and 19 - these columns were not used in this study.

Columns 20 and 21: Right Extra Ethmoidal Foramen (R. ET. FO.)

Left Extra Ethmoidal Foramen (L. ET. FO.)

0 = absent (normal configuration, 1 anterior, 1 posterior)

1 = 1 extra foramen present

2 = 2 extra foramina present

3 = 3 extra foramina present

4 = 4 extra foramina present

9 = posterior foramen absent

Columns 22 and 23: Right Anterior Ethmoidal Foramen Position
(R. ET. PO.)

Left Anterior Ethmoidal Foramen Position
(L. ET. PO.)

1 = foramen sutural (fronto-ethmoidal)

2 = foramen in frontal bone

3 = foramen in ethmoid bone

Column 24: Nasal Aperture Form (NAS. APT.)

1 = pyriform shaped

2 = inverted heart shaped

3 = equilateral triangle shaped

Column 25: Nasal Profile (NAS. PRO.)

1 = concave

2 = convex

3 = straight

4 = concavo-convex (a combination of the two)

Columns 26 and 27: Right Infraorbital Foramen (R. IN. OR.)

Left Infraorbital Foramen (L. IN. OR.)

1 = single foramen

2 = double foramina

3 = divided foramen

Columns 28 and 29: Right Zygomatico-facial Foramen (R. ZY. FO.)

Left Zygomatico-facial Foramen (L. ZY. FO.)

0 = absent

1 = single foramen

2 = 2 foramina

3 = 3 foramina

4 = 4 foramina

Columns 30 and 31: Right Os Japonicum (R. OS. JA.)

Left Os Japonicum (L. OS. JA.)

9 = present

0 = absent

1 = trace

Columns 32 and 33: Right Malar Tuberclle (R. MA. TU.)

Left Malar Tuberclle (L. MA. TU.)

0 = absent

1 = +

2 = ++

3 = +++

4 = +++++

Columns 34 and 35: Right Zygomatico-facial Foramen (R. ZY. TU.)

Left Zygomatico-facial Foramen (L. ZY. TU.)

0 = absent

1 = +
2 = ++
3 = +++
4 = +++++

Columns 36 and 37: Right Marginal Tuberclle (R. MG. TU.)
Left Marginal Tuberclle (L. MG. TU.)

0 = absent
1 = +
2 = ++
3 = +++
4 = +++++

Columns 38 to 40 - these columns were not used in this study.

Columns 41 and 42: Right Accessory Palatine Foramen (R. PL. FO.)
Left Accessory Palatine Foramen (L. PL. FO.)

0 = absent
1 = 1 accessory foramen
2 = 2 accessory foramina
3 = 3 accessory foramina
4 = 4 accessory foramina

Columns 43 and 44: Right Pterygoforamen (R. PT. FO.)
Left Pterygoforamen (L. PT. FO.)

0 = absent

1 = basal spur
2 = basal foramen
3 = spinous spur
4 = spinous foramen
5 = basal and spinous spurs
6 = basal and spinous foramina

Columns 45 and 46: Right Vesalian Foramen (R. VE. FO.)
Left Vesalian Foramen (L. VE. FO.)

9 = present
0 = absent

Columns 47 and 48: Right Ovale-Spinosum (R. OV. SP.)
Left Ovale-Spinsoum (L. OV. Sp.)

1 = common
2 = normal

Columns 49 and 50: Right Anterior Condylar Canal (R. AN. CC.)
Left Anterior Condylar Canal (L. AN. CC.)

1 = single
2 = divided
3 = spur (partially divided)

Columns 51 and 52: Right Posterior Condylar Canal (R. PO. CC.)
Left Posterior Condylar Canal (L. PO. CC.)

9 = present

0 = absent

Columns 53 and 54: Right Occipital Condyle (R. OC. CO.)

Left Occipital Condyle (L. OC. CO.)

1 = single

2 = double

3 = hourglass

Column 55: Precondylar Tuberclle (PRECOND.)

0 = absent

1 = +

2 = ++

3 = +++

4 = +++++

5 = complete articular facet

Column 56: Ossified Apical Ligament (APL. LIG.)

0 = absent

1 = +

2 = ++

3 = +++

4 = +++++

Columns 57 and 58: Right Paramastoid (R. PARAM.)

Left Paramastoid (L. PARAM.)

0 = absent

1 = +

2 = ++

3 = +++

4 = ++++

Columns 59 to 62 - These columns were not used in this study.

Column 63: Sagittal Sinus Direction (SAG. SIN.)

1 = right

2 = left

3 = common (bifurcating)

Columns 64 and 65: Right Parietal Foramen (R. PA. FO.)

Left Parietal Foramen (L. PA. FO.)

0 = absent

1 = 1 foramen

2 = 2 foramina

3 - 3 foramina

Column 66: Coronal Wormians (COR. WOR.)

0 = absent

1 = 1 wormian bone

2 = 2 wormian bones

3 = 3 wormian bones

4 = 4 wormian bones

5 = 5 or more wormian bones

6 = suture fused (trait unscorable)

Column 67: Bregmatic Bone (BRE. BON.)

9 = present

0 = absent

6 = suture fused (trait unscorable)

Column 68: Sagittal Wormians (SAG. WOR.)

0 = absent

1 = 1 wormian bone

2 = 2 wormian bones

3 = 3 wormian bones

4 = 4 wormian bones

5 = 5 or more wormian bones

6 = suture fused (trait unscorable)

Column 69: Lambdoid Wormians (LAM. WOR.)

0 = absent

1 = 1 wormian bone

2 = 2 wormian bones

3 = 3 wormian bones

4 = 4 wormian bones

5 = 5 or more wormian bones

6 = suture fused (trait unscorable)

Column 70: Lambdic Bone (LAM. BON.)

- 0 = absent
- 1 = trace of ossicle at lambda
- 2 = inca bone - ossified squamous portion of occipital bone with transverse occipital suture
- 3 = lambdic bone - ossicle at lambda
- 6 = suture fused (trait unscorable)

Columns 71 and 72: Right Pterion Shape (R. PT. SH.)

Left Pterion Shape (L. PT. SH.)

- 1 = H-shaped (parieto-sphenoid articulation)
- 2 = K-shaped (fronto-temporal articulation)
- 3 = X-shaped (fronto-parieto-spheno-temporal articulation)
- 4 = epipteric bone (ossicle at pterion)
- 5 = other
- 6 = suture fused (trait unscorable)

Columns 73 and 74: Right Parietal Notch (R. PA. NO.)

Left Parietal Notch (L. PA. NO.)

- 9 = notch present
- 0 = absent
- 1 = bone present

Columns 75 and 76: Right Asterionic Bone (R. AS. BO.)

Left Asterionic Bone (L. AS. BO.)

9 = present

0 = absent

CARD D

Columns 11 and 12: Right Mastoid Foramen (R. MA. FO.)

Left Mastoid Foramen (L. MA. FO.)

0 = absent

1 = 1 foramen

2 = 2 foramina

3 = 3 foramina

4 = 4 foramina

5 = 5 or more foramina

Columns 13 and 14: Right Mastoid Foramen Position (R. MA. PO.)

Left Mastoid Foramen Position (L. MA. PO.)

1 = occipital

2 = masto-occipital suture

3 = temporal

6 = suture fused (trait unscorable)

Columns 15 and 16: Right Divided Mastoid (R. DI. MA.)

Left Divided Mastoid (L. DI. MA.)

9 = present

0 = absent

1 = suture trace

Columns 17 and 18: Right Tympanic Dehiscience (R. TY. DE.)
Left Tympanic Dehiscience (L. TY. DE.)

9 = present

0 = absent

Columns 19 and 20: Right Tympanic Thickening (R. TY. TH.)
Left Tympanic Thickening (L. TY. TH.)

9 = present

0 = absent

(II) General Data Processing

Utilizing the facilities at McMaster University, Hamilton, Ontario, data were transferred from the original University of Toronto scoring blanks to standard 80 column computer punch cards using an I.B.M. card punch machine. These cards were then 'listed', that is printed out, by the computer and the printed lists were checked against the original blanks. Errors were thus detected, new cards punched, and the data 'de-bugged'.

With the data thus prepared it was possible to use a standard computer punch card sorting machine to determine the frequency of the various manifestations of the traits under study. By sorting the cards on each column separately, and recording the incidences of each code in each column as counted by the sorting machine, frequency tables for each trait were easily assembled. Further, using the material identification codes contained in the first 30 columns of each card, trait incidences could be recorded by age, sex, and population, or any inter-mixture of these classifications.

Following this general data processing, statistical analysis was carried out.

(III) Statistical Processing

Statistical processing of the data attempted an analysis of two kinds: 1) analysis of the internal relationships, if any, of the data taken as a corpus without regard as to population, and 2) analysis of the data in terms of interpopulational differences.

Internal analysis of the data is aimed at examining the relationship, if any, of sex and side (if bilateral) differences in the occurrence of traits and/or their various manifestations (see Chapter 1). This type of analysis involves collapsing, or reducing each trait into a bimodal present/absent dichotomy, thus allowing standard 2×2 chi-squared tests to be performed. The chi-squared test, while not measuring the degree or form of the relationship between two independent categories of classification, does tell whether they are or are not significantly related (Mills 1924).

For discontinuous traits in which only two expressions are possible (present/absent) no further reduction was needed for constructing chi-squared cells. For continuous traits the reduction to bimodal state attempted a distribution so as to maximize the weight of each cell, thus allowing the chi-squared test to be performed without Yates' correction for the discontinuity of the normal curve brought about by a small sample size. Yates' correction was used

when the size of any cell was less than 5. Gaherty (1970) has pointed out that this leads to rejection of homogeneity more often than is correct but that it is better to err on the conservative side.

The following is a list of the bimodal states to which each trait was reduced for chi-squared analysis. The trait abbreviations used are those shown earlier in this chapter, and the codes are contained in that part as well. It will be noted that the bimodal states contain only those codes which were observed.

Column 11 MET. SUT.

0/1+2+3
metopism absent/metopism present

Columns 12 R. and L. FR. GR.
and 13

0/9
grooves absent/grooves present

Column 14 BRW. SHP.

0+1/2+3
continuous brow absent/continuous brow present

Column 15 BRW. RUG.

0+1/2+3
slight expression or absent/slight expression present

Columns 16 R. and L. SU. OR.
and 17

0+1+3/2+4+5+7+9
multiple notch-foramen absent/multiple notch-foramen present

Columns 20 R. and L. ET. FO.
and 21

9+0/1+2+3
extra foramina absent/extra foramina present

Columns 22 R. and L. ET. PO.
and 23

2+3/1
sutural foramen absent/sutural foramen present

Column 24 NAS. APT.

2/1
pyriform absent/pyriform present

Column 25 NAS. PRO.

4/2
convex absent/convex present

Columns 26 R. and L. IN. OR.
and 27

2+3/1
single foramen absent/single foramen present

Columns 28 R. and L. ZY. FO.
and 29

0+1/2+3+4
multiple foramina absent/multiple foramina present

Columns 30 R. and L. OS. JA.
and 31

0/9+1
absent/present

Columns 32 R. and L. MA. TU.
and 33

0+1/2+3+4
slight expression or absent/greater expression

Columns 34
and 35 R. and L. ZY. TU.
 0+1/2+3+4
slight expression or absent/greater expression

Columns 36
and 37 R. and L. MG. TU.
 0+1/2+3+4
slight expression or absent/greater expression

Columns 41
and 42 R. and L. PL. FO.
 0/1+2+3+4
absent/present

Columns 43
and 44 R. and L. PT. FO.
 0/1+2+3+4
absent/present

Columns 45
and 46 R. and L. VE. FO.
 0/9
absent/present

Columns 47
and 48 R. and L. OV. SP.
 1/2
normal absent/normal present

Columns 49
and 50 R. and L. AN. CC.
 2+3/1
single canal absent/single canal present

Columns 51
and 52 R. and L. PO. CC.

0/9
canal absent/canal present

Columns 53
and 54 R. and L. OC. CO.

2+3/1
single condyle absent/single condyle present

Column 55 PRECOND.

0/1+2+3+4+5
tubercle absent/tubercle present

Column 56 APL. LIG.

0/1+2
absent/present

Columns 57
and 58 R. and L. PARAM.

0/1+2+3+4
absent/present

Column 63 SAG. SIN.

2+3/1
right absent/right present

Columns 64
and 65 R. and L. PA. FO.

0/1+2+3
absent/present

Column 66 COR. WOR.

0/1
absent/present

Column 67 BRE. BON.

0/9
absent/present

Column 68 SAG. WOR.

0/1+2
absent/present

Column 69 LAM. WOR.

0/1+2+3+4+5
absent/present

Column 70 LAM. BON.

0/1+2+3
absent/present

Columns 71

and 72 R. and L. PT. SH.

2+3+4/1
H-shape absent/H-shape present

Columns 73

and 74 R. and L. PA. NO.

0/9+1
bone or notch absent/bone or notch present

Columns 75
and 76 R. and L. AS. BO.
 0/9
 absent/present

Columns 11
and 12 R. and L. MA. FO.
 0+1/2+3+4
multiple foramina absent/multiple foramina present

Columns 13
and 14 R. and L. MA. PO.
 1+2/3
temporal absent/temporal present

Columns 15
and 16 R. and L. DI. MA.
 0/9+1
division absent/division present

Columns 17
and 18 R. and L. TY. DE.
 0/9
absent/present

Columns 19
and 20 R. and L. TY. TH.
 0/9
absent/present

Using the cells as defined above, the internal relationships of the data were examined for significant side and sex differences.

Analysis of interpopulational differences in the data were then undertaken. There are two techniques of interpreting the varying incidences of non-metric traits in different populations. The first of these is to trace the incidence of each trait observed in each of the populations being studied, and thereby determine which populations cluster together as high or low possessors of the different variants (see for example Hess 1945; Brothwell 1961).

The second method is to calculate a multivariable distance statistic which is a summation of any number of traits to express in one number the affinity between any two populations (Ossenberg 1969; Berry et al. 1967a; Knip 1971). Gaherty (1970) has recommended the use of a multivariable statistic in population studies based upon non-metric characters in order to keep track of the bulk of data derived from the various populations, and to balance out the random fluctuations in frequency due to sampling error which will arise given populations of small sample size:

It is unlikely that any small sample will differ markedly from the total population in more than a small proportion of traits, and (using a multivariable statistic) these deviations will tend to cancel each other out (Gaherty 1970:36).

Several multivariable statistics are available for use (see reviews by Gaherty 1970, 1974). Laughlin and Jørgensen (1956) and Brothwell (1959) have used an adaptation of Penrose's (1954) 'size and shape' statistic to differentiate populations, and Gaherty (1970) has used chi-squared, mean square distance, and Hiernaux's Δg in working with African populations. The most commonly used of these, and the one which Gaherty (1970) concludes is the best and most efficient, is the mean square distance based upon the "Euclidean distance between two points in n-dimensional space, where n is the number of traits used" (Gaherty 1970: 41 citing Sokal and Sneath 1963).

The mean square distance is here measured using C.A.B. Smith's coefficient of divergence. This statistic, introduced by Smith (Berry and Smith Ms.) and first used by Grewal (1962b) and Berry (1963) gives an estimate of the divergence of any two populations based upon the angular transformation into radians of raw percentages of trait incidence with correction for sample size. Gaherty (1974) has given this statistic as:

$$s^2_{jk} = \frac{1}{N} \sum (\theta_{ij} - \theta_{ik})^2 - \left(\frac{1}{n_{ij}} + \frac{1}{n_{ik}} \right)$$

where s^2_{jk} = the mean measure of divergence between populations j and k.

N = the number of traits used.

θ_{ij} = angular transformation of x_{ij} such that θ_{ij}
 $= \sin^{-1} (1-2x_{ij})$ where x_{ij} = the frequency
of the i^{th} trait for population j .

θ_{ik} = angular transformation of x_{ik} .

n_{ij} = sample size of i^{th} trait for population j .

n_{ik} = sample size of i^{th} trait for population k .

Berry (1974) recommends that the mean measure of divergence be converted to the estimate of divergence (s_{jk}) via the equation, $s_{jk} = \sqrt{s_{jk}^2}$. The larger the estimate of divergence the smaller the genetical relationship between the two populations is considered to be. Gaherty (personal communication) has recommended that for clarity's sake the estimate of divergence be thought of as linear units separating the two populations under study, though the estimate of divergence expresses phenotypic differences in terms of arbitrary units, not in terms of total genetical differences expressed as numbers of gene substitutions (Berry et al. 1967b).

The validity of this statistic has been discussed by Berry (1964), Berry et al. (1967b), Howe and Parsons (1967), and Berry and Smith (Ms.). Berry et al. (1967a) have found that non-metrical analysis using the C.A.B. Smith statistic yields results for ancient Egyptian populations that would be expected based upon cultural, archaeological, and metrical

data, and Berry et al. (1967b) and Berry and Smith (Ms.) report a positive correlation of 30-40% between results obtained with the Smith statistic and those obtained using metrical data. Knip (1971) states that when using the Smith statistic non-metrical measures of divergence reflect genetical differences better than statistics based upon metrical data.

CHAPTER 5

Results and Discussion

(I) Introduction

In this chapter the results of this study are described and tabulated, and those results discussed. These results are of two types; 1. results of observation such as age and sex distribution, and 2. results of computation such as chi-squared analysis. Discussion follows each tabulation of findings, and the chapter concludes with a summary of the overall findings and recommendations for future investigations utilizing this methodology. Note that in all tables the samples are listed in chronological sequence as established in Chapter 2.

Results of Observation

(II) Sex and Age Distribution

Tables 5.1 and 5.2 show the distribution of sexes and ages within the six samples. The distribution of males and females within each sample approximate one another and there is no discernible pattern of change.

Table 5.1
POPULATION DEMOGRAPHY

	Sex				Age				Total N		
	Male		Female		18-35		35-55		55+		
	N	%	N	%	N	%	N	%	N	%	
GAUL	27	43	36	57	33	53	26	42	3	5	63
FRNC.	34	53	30	47	42	66	21	33	1	1	64
BRGN.	9	40	14	60	13	57	9	39	1	4	23
MRVG.	23	50	23	50	15	33	27	59	4	8	46
CRLG.	30	56	24	44	16	30	37	69	1	1	54
BASQ.	13	46	15	54	13	46	15	54	0	0	28

Table 5.2

AGE BY SEX

	18-35				35-55				55+			
	Males		Females		Males		Females		Males		Females	
	N	%	N	%	N	%	N	%	N	%	N	%
GAUL	12	44	21	58	13	48	13	36	2	8	1	6
FRNC.	23	68	19	63	11	32	10	33	0	0	1	3
BRGN.	4	44	9	64	4	44	5	36	1	12	0	0
MRVG.	6	26	9	39	15	65	12	52	2	8	2	9
CRLG.	7	23	9	38	23	78	14	58	0	0	1	4
BASQ.	5	39	8	53	8	61	7	47	0	0	0	0

In the distribution of ages-at-death there is a pattern of change which indicates that in the presumably older samples people died at an earlier age than in the more modern ones. In other words a pattern of longer life span is indicated with the passage of time. This generalization should, however, be tempered with the realization that the sample size is small, and not necessarily a random one.

In Table 5.2 the age-at-death distribution is broken down by sex. From this breakdown it is evident that this increase in age-at-death is very nearly equally distributed between the sexes, though the males account for a bit more of the change than do the females. It is also evident that the greatest proportion of change is from the 18-35 to the 35-55 years-at-death categories.

That age-at-death rises over time (for example pre-versus post-Neolithic revolution) is an oft noted phenomenon (for example Angel 1971), and can be attributed to such factors as behavior, more competent medical care available to a broader range of the populace, more nutritious diet, superior sanitation, etc. It is beyond the scope of this study to analyze which of such factors are at work here.

Finnegan (1973) has found that the slight age-regressive nature of some cranial morphological traits is not enough to necessitate a correction before application

of a multivariable statistic, unless the combined populations produce a distinctly bimodal age curve. Clearly these six samples do not produce such a distribution and we need not worry, therefore, about the possible age correlation of variants when calculating biological divergence.

(III) Variant Incidence

Table 5.3 tabulates the incidence of the 'present' mode of each trait in the six samples. It shows this in the conventional manner; present/total number of specimens scored for the trait, and expresses this fraction as a percentage. In the case of bilaterally occurring traits the total number of sides scored is used in place of the total number of specimens.

For the four traits shown to be sexually dimorphic (see below) the data for males alone are given, while all other data represent the entire sample irrespective of sex. The number of specimens (or sides) scored varies since, because of breakage, not every skull allowed for the observation of every trait.

Using a table of angular transformations in radians (Berry and Berry 1971), the raw percentages of trait incidence shown in Table 5.3 were converted into radians

Table 5.3

POPULATION INCIDENCES OF CRANIAL MORPHOLOGICAL TRAITS

	Frequency						Percentage Incidence					
	GAUL	FRNC	BRGN	MRVG	CRLG	BASQ	GAUL	FRNC	BRGN	MRVG	CRLG	BASQ
Met. Sut.	8/61	11/63	10/23	7/46	5/53	4/28	13.1	17.5	43.5	15.2	9.4	14.3
Fr. Gr.	7/121	24/124	6/43	17/92	20/106	5/56	5.8	19.4	14.0	18.5	18.9	7.1
Brw. Shp.	23/55	54/60	9/21	22/46	11/51	9/28	41.8	90.0	42.9	47.8	21.6	32.1
Brw. Rug.	M22/25	32/34	9/9	22/23	28/28	12/13	88.0	94.1	100.0	95.7	100.0	92.3
Su. Orb.	14/112	23/120	2/41	25/92	31/103	19/56	12.5	19.2	4.9	27.2	30.1	33.9
Et. For.	15/41	10/17	12/18	15/40	25/60	14/42	36.6	58.8	66.7	37.5	41.7	33.3
Et. Pos.	22/38	7/19	12/20	25/41	19/64	9/42	57.9	36.8	60.0	61.0	29.7	21.4
Nas. Apt.	35/36	36/37	14/15	33/38	39/45	27/28	97.2	97.3	93.3	86.8	86.7	96.4
Nas. Prof.	14/28	10/35	1/10	1/21	0/41	1/24	50.0	28.6	10.0	4.8	0.0	4.2
In. Or.	62/67	60/63	26/29	65/74	77/84	39/52	92.5	95.2	89.7	87.8	91.7	75.0
Zy. For.	20/66	16/66	4/29	17/71	22/84	20/53	30.3	24.2	13.8	23.9	26.2	37.7
Os. Jap.	1/63	0/58	0/27	3/66	4/81	3/49	1.6	0.0	0.0	4.5	4.9	6.1
Ma. Tub.	M 6/23	9/34	8/16	20/34	34/48	17/23	26.1	26.5	50.0	58.8	70.8	73.9
Zy. Tub.	M16/24	29/33	13/16	23/34	33/47	15/23	66.7	87.9	81.2	67.6	70.2	65.2
Mg. Tub.	38/66	42/63	15/29	44/71	33/84	26/53	57.6	66.7	51.7	62.0	39.3	49.1
Pl. For.	29/60	22/37	17/28	35/63	38/77	25/52	48.3	59.5	60.7	55.6	49.3	48.1
Pt. For.	2/59	6/46	2/27	1/71	13/88	3/56	3.4	13.0	7.4	1.4	14.8	5.4
Ve. For.	33/63	43/71	18/32	37/81	32/94	11/56	52.4	60.6	56.3	45.7	34.0	19.6
Ov. Sp.	6/67	9/75	0/32	2/82	1/99	0/56	9.0	12.0	0.0	2.4	1.0	0.0
An. Cc.	49/66	54/69	24/29	62/78	54/87	40/56	74.2	78.3	82.8	79.5	62.1	71.4

Table 5.3 continued

POPULATION INCIDENCES OF CRANIAL MORPHOLOGICAL TRAITS

	Frequency						Percentage Incidence					
	GAUL	FRNC	BRGN	MRVG	CRLG	BASQ	GAUL	FRNC	BRGN	MRVG	CRLG	BASQ
Po. Cc.	38/58	39/61	12/26	50/71	51/83	43/55	65.5	63.9	46.2	70.4	61.5	78.2
Oc. Co.	60/63	56/58	25/25	63/70	76/81	49/56	95.2	96.5	100.0	90.0	93.8	87.5
Precond.	24/32	18/33	10/14	13/37	15/43	4/27	75.0	54.5	71.4	35.1	34.9	14.8
Apl. Lig.	5/32	5/34	0/15	2/36	9/44	6/28	15.6	14.7	0.0	5.6	20.5	21.4
Param.	26/68	21/72	19/33	46/74	18/85	19/56	38.2	29.2	57.6	62.2	21.2	33.9
Sag. Sin.	34/44	35/55	17/19	41/45	47/50	19/25	77.3	63.6	89.5	91.1	94.0	76.0
PA.Fo.M.	19/52	16/66	11/18	24/43	25/56	12/26	36.5	24.2	61.1	55.8	44.6	46.1
Cor. Wor.	1/51	1/43	0/19	0/45	2/50	0/28	2.0	2.3	0.0	0.0	4.0	0.0
Bre. Bon.	0/55	0/45	0/20	0/44	0/49	0/28	0.0	0.0	0.0	0.0	0.0	0.0
Sag. Wor.	2/48	2/35	0/20	2/40	2/41	0/26	4.2	5.7	0.0	5.0	4.9	0.0
Lam. Wor.	12/46	7/36	8/20	6/43	7/45	12/26	26.1	19.4	40.0	14.0	15.6	46.2
Lam. Bon.	8/51	9/47	0/20	5/44	5/46	4/28	15.7	19.1	0.0	11.4	10.9	14.3
Pt. Shp.	45/48	59/61	27/28	55/59	58/69	45/47	93.8	96.7	96.4	93.2	84.1	95.7
Pa. No.	55/92	56/93	24/42	59/89	77/105	27/56	59.8	60.2	57.1	66.3	73.3	48.2
As. Bon.	14/80	12/95	1/43	2/86	9/106	9/56	17.5	12.6	2.3	2.3	8.5	16.1
Ma. For.	33/90	23/89	11/33	21/85	41/104	24/56	36.7	25.8	33.3	24.7	39.4	42.9
Ma. Po.	48/73	47/72	16/27	41/70	48/92	38/53	65.8	65.3	59.3	58.6	52.2	71.7
Di. Ma.	21/91	30/88	10/43	35/87	17/106	14/56	23.1	34.1	23.3	40.2	16.0	25.0
Ty. De.	6/92	12/96	4/45	14/88	14/106	6/56	6.5	12.5	8.9	15.9	13.2	10.7
Ty. Th.	54/95	51/96	18/45	34/84	58/105	28/56	56.8	53.1	40.0	40.5	55.2	50.0

(Table 5.4). These conversions were then used in biological distance computation (see below).

Results of Computation

(IV) Side-by-Side Correlation

Chi-squared analysis was performed on all bilaterally occurring traits to determine if the absence of side-by-side correlation reported by others (for example Gaherty 1970; Finnegan 1973a) could be confirmed here. The results of these tests are shown in Table 5.5 and do indeed confirm those previous findings. Of the 162 tests only 2 showed significance at the $p > .05$ level of probability. Gaherty (1970) notes that in a large series of chi-squared tests a sampling error equal to the probability at which significance is taken can be expected. Therefore we may expect 5% of the 162 tests to show spurious significance. As but 1.2% of our tests show significance we are fully justified in concluding that, 1. in these samples there is no significant correlation between the right and left sides in bilaterally occurring traits, and 2. we may therefore pool data from the two sides together as was done in Table 5.3.

Table 5.4
ANGULAR TRANSFORMATIONS INTO RADIANS

	GAUL	FRNC	BRGN	MRVG	CRLG	BASQ
Met. Sut.	.830	.708	.130	.770	.948	.795
Fr. Gr.	1.084	.659	.804	.682	.671	1.031
Brw. Shp.	.177	-.927	.159	.056	.604	.349
Brw. Rug.	M-.863	-1.080	-1.571	-1.153	-1.571	-1.008
Su. Orb.	-.848	-.664	-1.124	-.474	-.409	-.328
Et. For.	.271	-.177	-.341	.253	.167	.341
Et. Pos.	-.142	.267	-.201	-.222	.418	.609
Nas. Apt.	-1.235	-1.241	-1.047	-.827	-.824	-1.189
Nas. Prof.	.000	.442	.927	1.129	1.571	1.158
In. Or.	-1.016	-1.129	-.917	-.857	-.986	-.524
Zy. For.	-.405	-.542	-.810	-.549	-.496	-.249
Os. Jap.	1.317	1.571	1.571	1.143	1.124	1.072
Ma. Tub.	M .498	.489	.000	-.177	-.429	-.498
Zy. Tub.	M-.341	-.860	-.674	-.360	-.416	-.309
Mg. Tub.	-.153	-.341	-.034	-.242	.208	.002
Pl. For.	.034	-.191	-.216	-.112	.014	.038
Pt. For.	1.200	.833	1.020	1.333	.781	1.102
Ve. For.	-.048	-.214	-.126	.086	.326	.654
Ov. Sp.	.961	.863	1.571	1.260	1.371	1.571
An. Cc.	-.505	-.602	-.716	-.631	-.244	-.442
Po. Cc.	-.315	-.282	.076	-.420	-.232	-.600
Oc. Co.	-1.129	-1.194	-1.571	-.927	-1.068	-.848
Precond.	-.524	-.090	-.442	.303	.307	.781
Apl. Lig.	.759	.784	1.571	1.093	.631	.609
Param.	.238	.429	-.153	-.247	.614	.328
Sag. Sin.	-.578	-.276	-.911	-.965	-1.076	-.547
Pa.Fo.	M .273	.542	-.224	-.116	.108	.078
Cor. Wor.	1.287	1.266	1.571	1.571	1.168	1.571

Table 5.4 continued

ANGULAR TRANSFORMATIONS INTO RADIANS

	GAUL	FRNC	BRGN	MRVG	CRLG	BASQ
Bre. Bo.	1.571	1.571	1.571	1.571	1.571	1.571
Sag. Wor.	1.158	1.089	1.571	1.120	1.124	1.571
Lam. Wor.	.498	.659	.201	.804	.759	.076
Lam. Bo.	.756	.666	1.571	.882	.898	.795
Pt. Sh.	-1.068	-1.205	-1.189	-1.043	-.751	-1.153
Pa. No.	-.197	-.205	-.142	-.332	-.485	.024
As. Bo.	.708	.845	1.266	1.266	.979	.745
Ma. For.	.278	.519	.332	.531	.210	.159
Ma. Po.	-.322	-.311	-.187	-.173	-.044	-.449
Di. Ma.	.568	.324	.563	.197	.748	.524
Ty. De.	1.055	.848	.965	.751	.827	.904
Ty. Th.	-.136	-.062	.201	.191	-.104	.000

Table 5.5

CHI-SQUARED ANALYSIS OF SIDE-BY-SIDE CORRELATION

	GAUL	FRNC	BRGN	MRVG	CRLG	BASQ
Fr. Gr.	0.0005	0.1344	0.1434	0.2886	0.0616	0.2692
Su. Orb.	0.0816	0.0204	0.4758	0.0549	1.0190	0.3186
Et. For.	0.0140	0.2354	4.0000*	0.0601	1.1918	0.5846
Et. Pos.	0.1451	0.3258	0.3030	0.1982	0.0264	0.8359
In. Or.	0.0012	0.0007	0.4532	0.0074	0.5241	0.2311
Zy. For.	1.0331	0.0000	0.2157	0.0044	0.2463	0.0311
Os. Jap.	0.0127	0.0000	0.0000	0.0028	0.2376	0.0013
Ma. Tub.	0.1370	0.0114	1.7676	0.5528	0.0126	0.0655
Zy. Tub.	0.3743	0.0011	2.4888	0.2737	0.1473	0.1701
Mg. Tub.	0.0823	0.3913	0.0369	0.0229	1.2477	0.0181
Pl. Fo.	1.0869	1.0464	7.3368**	0.4581	0.1179	0.0001
Pt. Fo.	0.4831	0.1916	0.4635	0.0002	0.3610	0.0000
Ve. Fo.	0.1478	1.1389	0.5079	0.5946	0.3406	0.4525
Ov. Sp.	0.0517	0.0018	0.0000	0.5125	0.0001	0.0000
An. Cc.	2.8523	3.7767	0.3325	0.0273	0.0188	0.0875
Po. Cc.	0.0000	0.1911	0.1805	0.3564	0.6645	1.1052
Oc. Co.	0.0007	0.5178	0.0000	0.5147	0.8009	0.0000
Param.	0.0951	0.0116	0.0411	0.0888	0.3946	0.0000
Pa. Fo.	0.3343	1.9050	1.5827	0.5725	0.0439	0.0000
Pt. Sh.	0.0055	0.4212	1.0370	0.1706	0.0690	0.4789
Pa. No.	0.4068	0.5182	0.0019	0.1390	0.3821	0.0715
As. Bo.	1.6048	0.0129	0.0005	0.5119	0.0035	2.1182
Ma. Fo.	0.1438	0.4407	1.5165	0.0983	0.0018	0.2916
Ma. Po.	1.3572	0.1595	0.7670	0.1970	0.0559	0.0074
Di. Ma.	0.8139	0.3639	0.0767	0.0020	0.0000	2.3809
Ty. De.	0.1782	1.9319	0.2278	0.1476	0.7406	0.1866
Ty. Th.	0.0879	0.0320	0.0333	0.0700	0.0807	0.0000

* p. > .05

** p. > .01

(V) Age Correlation

As indicated previously these samples do not produce a distinctly bimodal age distribution and therefore need not be tested for age correlation among the variants. This unimodal distribution is due, at least in part, to restricting study crania to those over 18-21 years of age. In any case the method used for age determination, exocranial suture closure, is a highly variable phenomenon and does not supply rigorous determinations of age. Therefore these samples would make unreliable test material for an age correlation analysis.

(VI) Inter-Trait Correlation

The possible correlation between individual non-metrical variants themselves was not tested in this study. This is primarily because the sample size is a good deal smaller than that which is desirable to check inter-trait correlation (Hertzog 1968, for example, uses samples of several hundred). For this reason Ossenberg's (1970:357) conclusion is assumed:

. . . correlation in pairs of the minor variants is generally either absent or at a very low level.

(VII) Sex Correlation

Chi-squared tests were performed to reveal if a null hypothesis for sex differences, as put forth by Berry and Berry (1967) and Ossenberg (1970) among others, held true for these samples. The Basque sample was chosen for this testing for being the best preserved and therefore presumably the most accurately anthroposcopically sexed. It is logical to assume that this series will best reveal the presence, if any, of sexual differences in the occurrence of variants.

The results of this testing, as tabulated in Table 5.6, tend to support the null hypothesis for sexual differences, that is that sexual dimorphism is either absent or at a very low level in the vast majority of non-metrical cranial morphological traits. Table 5.6 shows the test data as frequencies (present/total observed) and chi-squared values, and it should be noted that the Basque sample contains approximately equal numbers of males and females.

The following traits show sexual dimorphism at the $p > .05$ level:

brow rugosity	(males higher)
marginal tubercle	(males higher)
zygo-maxillary tubercle	(males higher)
parietal foramina	(males higher)

Table 5.6

SEX DIFFERENCES: BASQUES

<u>Trait</u>	Males n=13	Females n=15	<u>χ^2</u>
Met. Sut.	3/13	1/15	1.5316
Fr. Gr.	0/26	4/30	1.9936
Brw. Shp.	6/13	3/15	2.1840
Brw. Rug.	12/13	3/15	14.6395***
Su. Orb.	6/26	13/30	1.7259
Et. For.	7/17	7/25	0.3088
Et. Pos.	4/18	5/24	0.0736
Nas. Apt.	13/13	14/15	0.8987
Nas. Prof.	1/13	0/11	0.8829
In. Or.	17/25	22/27	0.6419
Zy. For.	9/25	11/28	0.0014
Os. Jap.	2/23	1/26	0.0120
Mg. Tub.	17/23	2/28	21.3116***
Zy. Tub.	15/23	6/26	7.2124**
Mg. Tub.	11/25	15/28	0.4841
Pl. For.	15/25	10/27	2.7419
Pt. For.	1/26	2/30	0.0162
Ve. For.	2/26	9/30	3.0916
Ov. Sp.	0/26	0/30	0.0000
An. Cc.	20/26	20/30	0.0033
Po. Cc.	19/26	24/29	0.2926
Oc. Co.	20/26	29/30	3.3230
Precond.	3/12	1/15	1.7755
Apl. Lig.	6/13	3/15	2.1840
Param.	11/26	8/30	0.9023
Sag. Sin.	10/12	9/13	0.6803
Pa. For.	12/26	24/30	5.5537*
Cor. Wor.	0/13	0.15	0.0000

Table 5.6 continued

SEX DIFFERENCES: BASQUES

<u>Trait</u>	<u>Males</u> n=13	<u>Females</u> n=15	<u>χ^2</u>
Bre. Bon.	0/13	0/15	0.0000
Sag. Wor.	0/12	0/14	0.0000
Lam. Wor.	5/13	7/13	0.6190
Lam. Bon.	2/13	2/15	0.1459
Pt. Sh.	20/21	25/26	0.3273
Pa. No.	13/26	14/30	0.0619
As. Bon.	4/26	5/30	0.0549
Ma. Fo.	15/26	9/30	3.3040
Ma. Po.	16/24	22/29	0.1878
Di. Ma.	5/26	9/30	0.3829
Ty. De.	4/26	2/30	0.3829
Ty. Th.	10/26	18/30	2.5846

* p > .05

** p > .01

*** p > .001

Of these the first three may be attributed to the characteristically heavier buttressing and more powerful musculature of the male skull. The two tubercles act as muscle origins, as described earlier, and the bony development of the brow is a buttress which protects the supra-orbital and -nasionic regions.

Multiplicity of the parietal foramen is here found to be more prevalent in males. This finding is supported by Ossenberg (1970) and Halpren (1973), while Akabori (1933), DeVilliers (1968), Jantz (1970), and Gaherty (1970) did not find sex differences in the incidence of parietal foramina significant.

In the case of these traits shown to be sexually dimorphic only the male data were used in computing biological distance following Gaherty's (1973) example.

(VIII) Biological Distance

As described earlier (Chapter 4) the estimate of biological divergence was computed using the C.A.B. Smith statistic which gives an estimate of the divergence between any two populations based upon the angular transformation into radians of raw percentages of trait incidence with correction for sample size. Raw percentages of trait incidence (Table 5.3) were transformed into radians (Table

Table 5.7

ESTIMATES OF BIOLOGICAL DIVERGENCE (s_{jk})

	GAUL	FRNC.	BRGN.	MRVG.	CRLG.	BASQ.
GAUL		.195777	.312960	.287360	.384539	.356531
FRNC.			.351874	.330209	.414503	.410953
BRGN.				.240181	.368289	.403111
MRVG.					.279016	.257968
CRLG.						.229995
BASQ.						

5.4) using a table of angular transformation supplied by Berry and Berry (1971). Estimates of divergence were then calculated (Table 5.7) in which the larger the value of s_{jk} the smaller the genetical relationship between the two populations is considered to be.

The results of these computations tend in general to support those predictions of biological affinity made in Chapter 2.

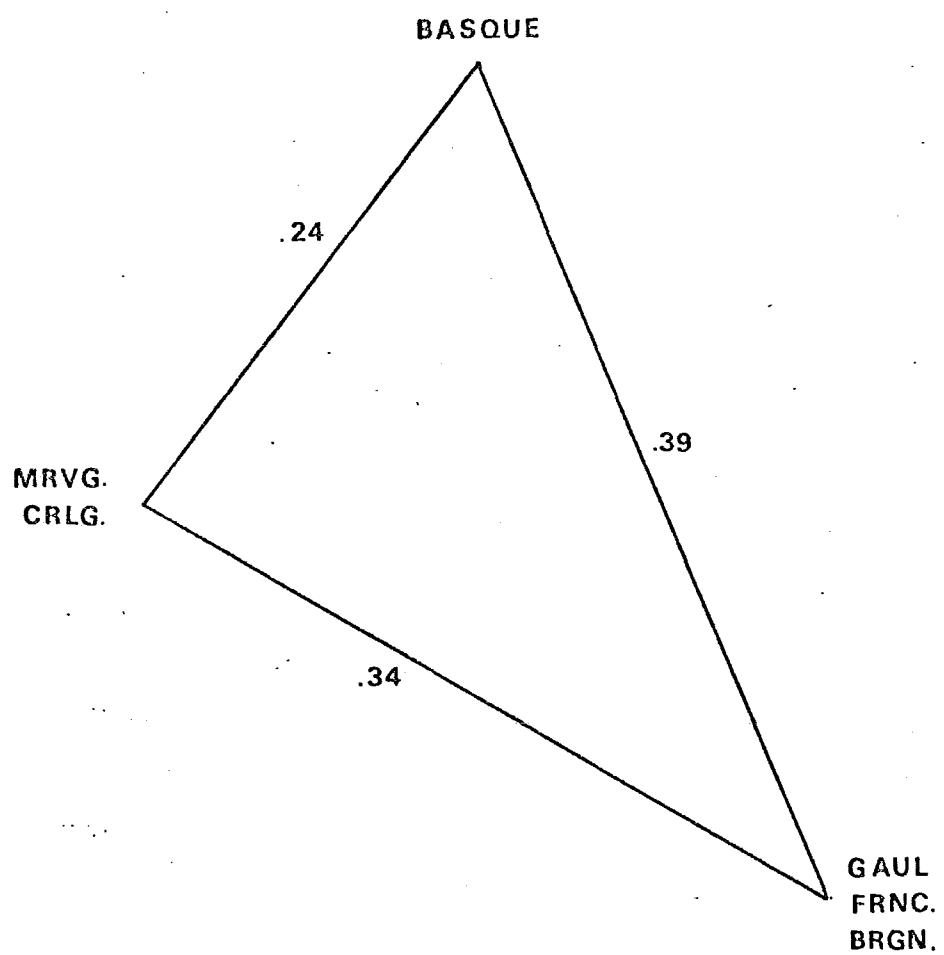
The first such prediction was that the non-northern European Basques would show closer biological affinity for the Frankish descendants (Merovingians and Carolingians) than for the northern European Gauls, Franks, and Burgondes. By averaging the estimates of biological divergence between the Basques and the three northern European groups, and doing the same for the estimates to the two Frankish descendants, it can be seen (Figure 5.1) that the Basques are nearly twice as close to the Merovingians and Carolingians as they are to the Gauls, Franks, and Burgondes. In Figure 5.1, and all subsequent figures, the value of s_{jk} is multiplied by 30 and then read in centimeters and plotted, for example $.123816 \times 30 = 3.7$ cm.

The relationship of the Basques to the other populations may be accounted for by recalling that the Basque sample is presumed modern and that the Merovingians and Carolingians are therefore chronologically closest to them.

Figure 5.1

Biological Divergence:

Basque, Frankish,
and Northern European



In fact the Carolingian sample is closer than the Merovingian, just as the Carolingians are closer chronologically. In addition is the fact that whereas the Gauls, Franks, and Burgondes are direct descendants of northern European groups, the Merovingians and Carolingians are further removed from their precursors and may therefore be expected to have lost, through micro-evolutionary processes and genetic admixture with non-northern European peoples, some of their distinction from the non-northern European Basques.

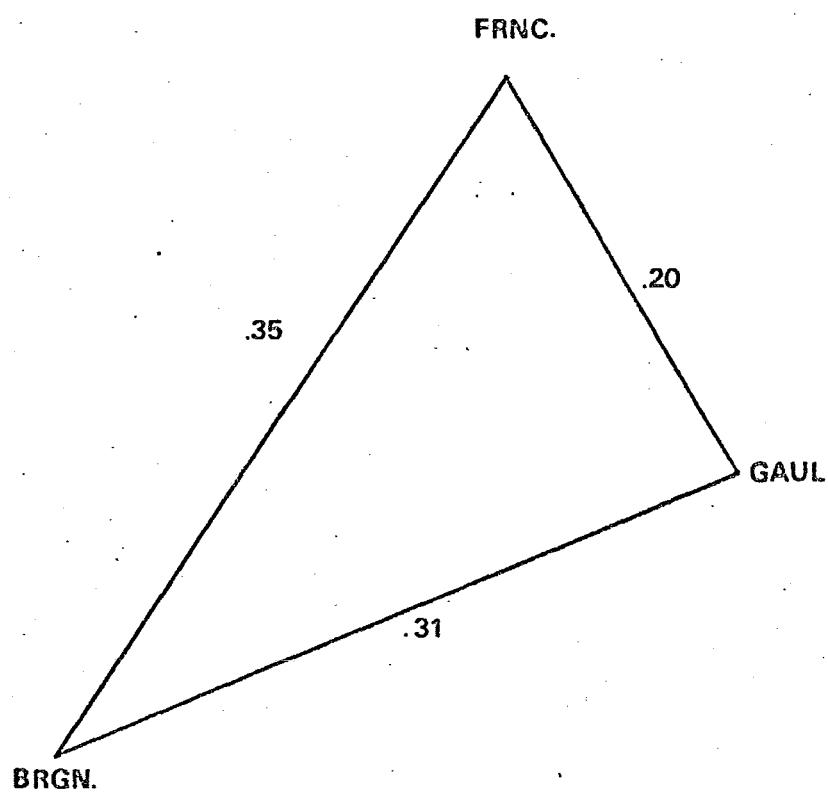
It was predicted that of the three northern European groups a closer affinity between the Gauls and Franks could be envisioned than between the Burgondes and either of those groups. This was based primarily upon the common territory inhabited by the Gauls and Franks after circa 300 A.D., though the reportedly pure Scandinavian homeland of the Burgondes versus the southwest German territory of the Gauls and Franks may have been a contributing factor.

As measured by the estimate of biological divergence of populations, and as plotted in Figure 5.2, this prediction was correct. The estimate of divergence between the Burgondes and Franks and Burgondes and Gauls is at least one and one-half times greater than that between the Gauls and Franks. This confirmation of the prediction must be viewed as supporting not the alleged Scandinavian homeland of the

Figure 5.2.

Biological Divergence:

Northern European



Burgondes, but rather the period of genetic contact between the Gauls and Franks.

A third prediction made was that, of the Merovingians and Carolingians, the former could be expected to be more closely aligned with the Franks, owing to the Merovingians' being closer to the Franks chronologically and their having absorbed fewer non-Frankish peoples than the empire-building Carolingians. In addition the Merovingians and Carolingians could be expected to show strong biological ties, being antecedents of one another. Table 5.7 and Figure 5.3 show that the data tend to confirm these predictions. The Merovingians are indeed 25% closer to the Franks than are the Carolingians, and the relationship between the Merovingians and Carolingians is closer than that between either of those groups and the ancestral Franks.

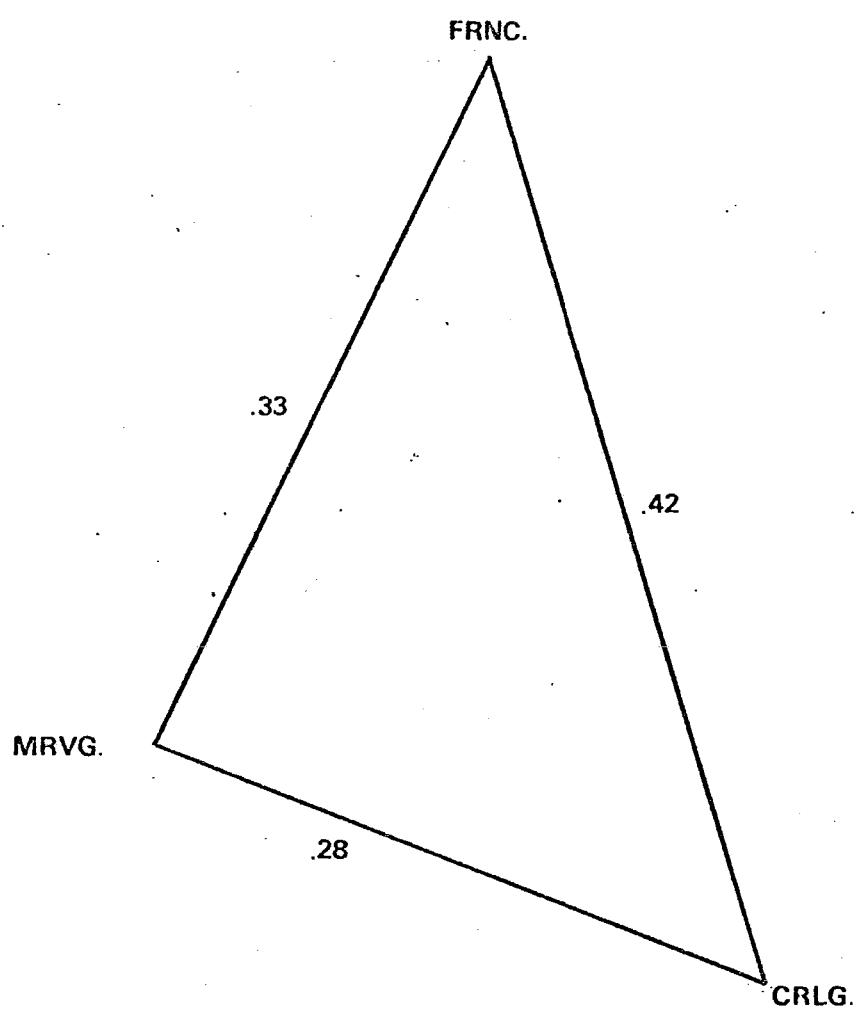
It would thus appear that the term 'Merovingian', as used by the Musée de l'Homme, is more a strictly political designation than is 'Carolingian', for the Carolingians possess a clearer biological distinction from the Franks than do the Merovingians.

One of the problems encountered in this study was the lack of exact placement of samples within time. The extent of biological divergence of the Burgondes from the other northern European and Frankish groups helps to estimate the

Figure 5.3

Biological Divergence:

Frankish



position of the Burgundian sample in the chronology of Burgundian history. The estimate of divergence between the Burgondes and the other northern European and Frankish peoples is a function of time in that, with the exception of the Merovingians, biological divergence increases with the modernity of the population (Figure 5.4). Thus the Burgondes are more closely aligned with the Merovingians, who conquered their Savoy kingdom in 534 A.D., than with any other group.

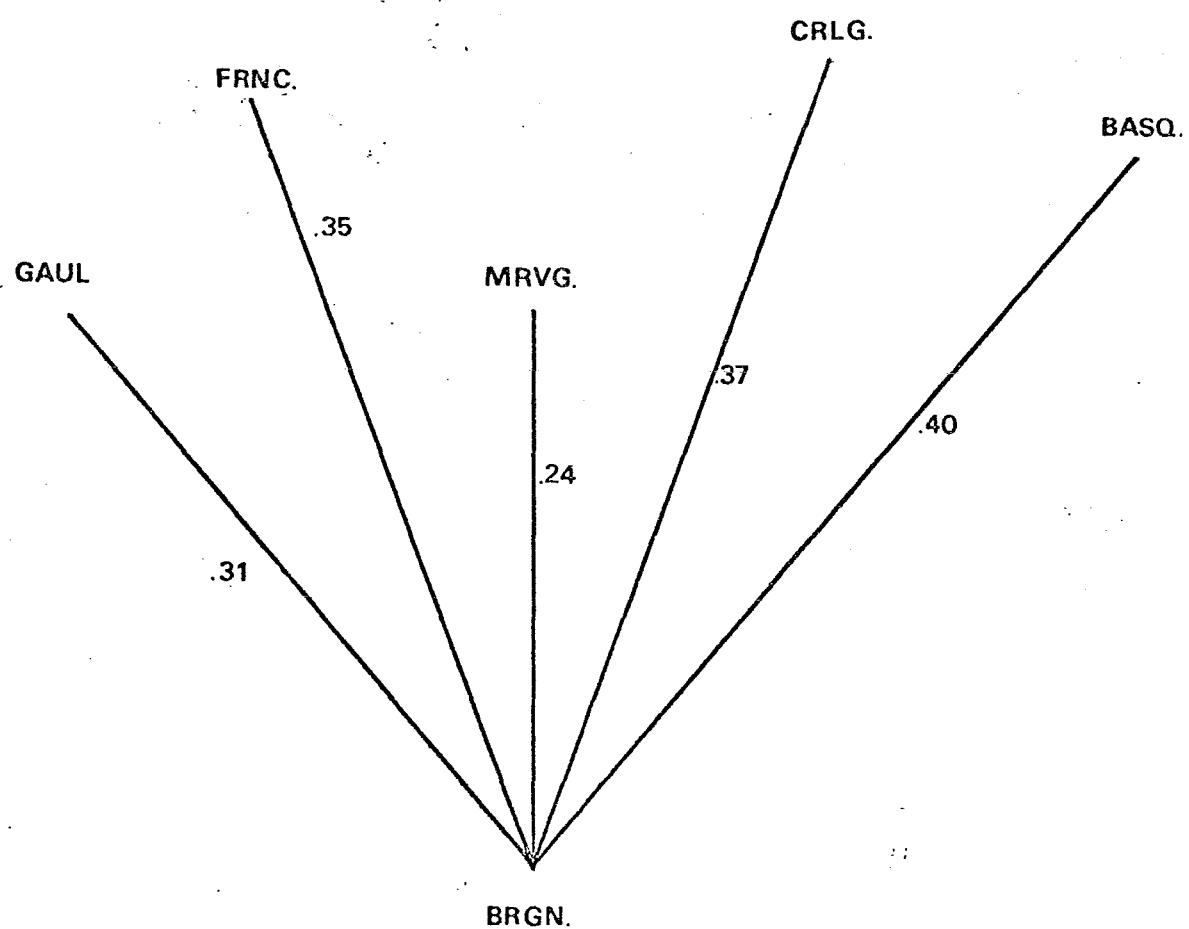
This low level of divergence between Burgonde and Merovingian suggests that the Burgonde sample dates from sometime after the Merovingians victory. In addition the Burgondes are 30% closer to the Merovingians than to the Merovingian ancestors, the Franks. This would indicate that the Burgonde sample is one drawn from a population which has had considerable admixture with the Merovingian gene pool.

In sum, the biological affinities of the Burgondes for the other four northern European and Frankish populations suggests that with the Merovingians' victory of 534 A.D. the Burgondes, through absorption into the Merovingians, lost a considerable amount of the genetical distinction that they may once have possessed vis-a-vis other northern European groups, and that the loss of their Savoy kingdom

Figure 5.4

Biological Divergence:

Burgundian



may have resulted in genetical, as well as cultural, political, and linguistic, adulteration.

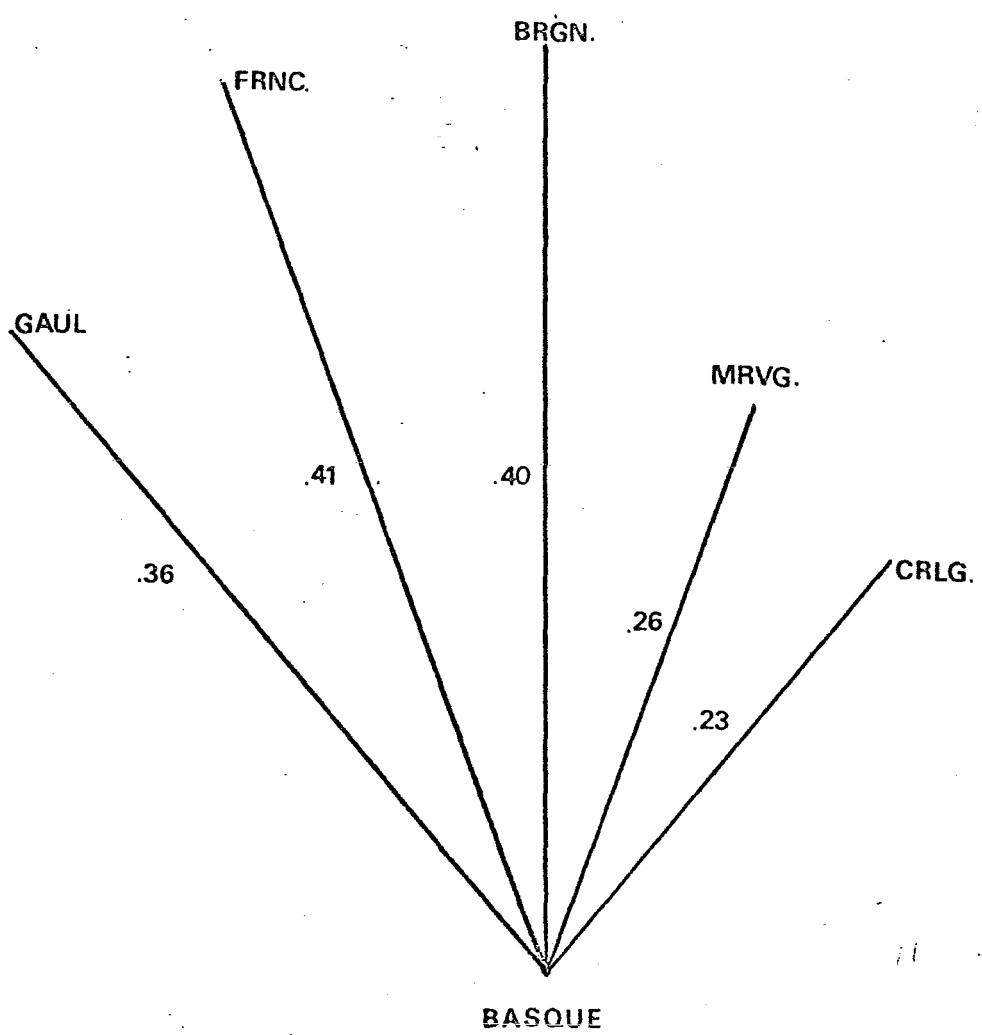
The extent of biological divergence also aids in illuminating the temporal position of the Basque sample. The fact that the Basques show greatest affinity for the Carolingians (Figure 5.5) tends to confirm the observation that the Basque sample is most probably of modern derivation. Thus although the Basque people were certainly established in their western Pyrenees territory long before the Carolingian emergence, the geographical proximity of the two groups, and the probable heavy genetic contribution by the Basques to the gene pool of modern Western Europe combine to give the Basques closer biological affiliation with the Carolingians than with any other group. The considerable lack of affinity that the Basques show for the three northern European groups serves to confirm their non-northern European origins, without indicating whether an Alpine or Mediterranean origin is more appropriate.

To summarize, this study has been able to distinguish several types of biological relationships between Gaul, Frank, Burgonde, Merovingian, Carolingian, and Basque samples. These biological relationships tend to confirm hypotheses of population affinity predicated upon available historical documentation.

Figure 5.5

Biological Divergence:

Basque



The results of chi-squared analysis confirm that both sex and side-by-side correlations with the incidence of non-metrical cranial variants are either absent or at a very low level, and that when these data are interpreted with the C.A.B. Smith measure of biological divergence, it is possible to distinguish between, and indicate the degree of relatedness of, several historically affiliated groups. These results are therefore not in conflict with the hypothesis that population differences in frequencies of non-metrical cranial variants are, at least partially, genetically mediated.

(IX) Methodological Considerations

The use of non-metrical methodology offers several advantages to the investigator in that the variants are quick and easy to observe and record, the method yields useful data from fragmented materials, and the data need seldom be corrected for sex, age, side, or inter-trait correlations, so that statistical interpretation is facilitated. In light of such advantages this methodology was chosen for use in the present study. In the course of this thesis several short comings of this methodology have been considered and they will be reviewed here.

Studies utilizing non-metrical variants as indicators of population divergence rely upon the assessment of phenotypic entities and their underlying genetic bases. Thus the understanding of those genetic bases and a rigorous standardization of phenotypic observations are called for.

The understanding of the genetical bases for epigenetic variation is, as pointed out earlier, as yet incomplete. The work of Grünberg and others has to date shown that epigenetic variation is at least in some cases, the result of, (1) the underlying continuous variable influenced by the action of several genes, and (2) the discontinuity imposed during embryonic development by an inherited threshold mechanism. However, while some epigenetic traits are "predominantly genetic in their mode of production" (Ossenberg 1970:369), non-genetic factors such as maternal diet, age, and litter size (among non-humans) may influence trait expression. Clearly then prime foci for understanding the genetics of non-metrical variation are first, the differentiation of traits which are of simple monogenic, versus polygenic, inheritance, and second the delineation, analysis, and understanding of the various contributions of genes and environment to phenotypic expression.

The problem of the lack of standardization of observation of those phenotypic expressions has been best pointed out by Finnegan (1973a) who observed that data

derived from non-metrical analysis is usually egocentric, as other workers regard the data as unusable owing to the lack of precise trait definition. Non-metrical methodology suffers greatly because of this. The work of Comas (1960) and others in providing basic definitions, techniques, and standards to anthropometry is without parallel in non-metrical literature. Thus an effort in that direction is sorely needed. The definitions and descriptions of traits given in this thesis it is hoped, are a step in that direction.

(X) Conclusions

The purpose of this study, as outlined in Chapter 1, is an examination of the biological affinities among six Western European populations in order to determine the extent to which historical accounts accurately reflect the affinities among those populations. It has been shown that the general predictions made on the basis of those sources are upheld by the biological data. It must, however, be stressed that this study has in fact established the extent of biological divergence between six samples which are attributed to those populations, and not to those populations themselves. Therefore, the conclusions reached are strictly applicable only to those samples and not to the populations as a whole.

In summation several concluding points may be stated:

1. Measures of biological divergence between northern European and northern European, northern European and Frankish, and non-northern European and Frankish samples all are in agreement with historically based predictions of relatedness.

2. The agreement between historical and biological data indicates that the Musée de l'Homme population designations are in general valid.

3. Merovingians show a lower level of divergence from ancestral Franks than do Carolingians, so that the term 'Merovingian' possesses less biological distinctiveness than does 'Carolingian'.

4. The Burgundian samples' affinity for the Merovingian indicates that the Burgonde sample is drawn from a population which postdates the 534 A.D. destruction of the Savoy kingdom of Burgundy, and which has had considerable admixture with the Merovingian gene pool.

5. The Basque sample, with its close affinity for the Carolingian, is most probably a modern one as suggested.

6. Both side-by-side and sex correlations with the incidence of non-metrical cranial variants are low enough that they do not affect the measures of biological divergence in any significant way.

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